IMPERIAL MYCOLOGICAL
28 DEC. 1938
INSTITUTE

BULLETIN No. 16.

Department of Agriculture,
Gold Coast.

# YEAR-BOOK 1928.

Issued by
The Director of Agriculture.
1929.

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## PAPER No. I.

# LOCAL CACAO PRICES AND THE STANDARDIZATION OF QUALITY.

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The task of reaping, preparing, centralizing and marketing the thousands of small lots which compose the 220,000 tons of cacao exported annually from the Gold Coast is not an easy one. It has been made more difficult by the rapid rate of growth of the industry. During the past 15 years the rate of increase has been 40,000 acres (10,000 tons) per annum.

In order to keep pace with this rapid growth, methods of preparation, centralization and finance have had to be improvised under the stress of urgency, the three tasks falling respectively to the farmer, the broker and the merchant. The main purposes have been achieved, but the methods do not work without friction. Quality is unsatisfactory, methods of centralization are wasteful, and financing is attended with unnecessary risks.

It is becoming more and more clear that the industry has outgrown devices which in the beginning were reckoned adequate, and that a revision of methods is necessary. The following memorandum embodies the views of the Department of Agriculture on the problem.

G. AUCHINLECK,
*Director of Agriculture.*

Area of farms.

The total area of cacao-farms on the Gold Coast is estimated to be about 900,000 acres. The figure is possibly too low, since it is based on the mean yield (595 pounds per acre) of nine fields of Forastero Cacao on Experiment Stations for an aggregate of 93 years, and a mean annual export of 220,000 tons. It is accurate enough, however, to give a correct impression of the magnitude of the effort involved in the task of collecting and centralizing the product

Number of farmers.

The produce of this area is owned by a large number of peasant-farmers. The number is not known with any degree of certainty, since no census of distribution and ownership has yet been made. Partly

from consideration of figures of the 1921 General Census and partly from observations made by officers, the Department of Agriculture estimates that the number of owners is probably not less than 150,000. On this basis, and with the knowledge that there are few large plantation-owners, the average area owned by a farmer is probably about 6 acres with an annual out-turn of 1½ tons of cacao each.

Small-scale operations.

In general, bulking of the produce from several farms is not practised. Each farmer reaps, prepares, and markets his produce independently. In many cases the area owned by an individual farmer is composed of more than one holding, and usually the crop from each holding is reaped four times annually. It is probable, therefore, that the number of lots reaped, prepared and sold separately is very large.

On a basis of 150,000 owners, with two holdings each and reaping four times annually, the annual export of 220,000 tons is probably composed of 1,200,000 lots of 400 pounds each. The figure may be an underestimate, since fermentation heaps rarely are so great as 400 pounds.

Resulting mixed quality.

We are therefore dealing with a peasant-industry, and furthermore with an unorganized peasant-industry. In every country, the recognised defect of this type of industry is lack of uniformity in the quality of produce. During 1927 and 1928 the Department of Agriculture has examined 121,321 samples of cacao representing a total of 342,943 tons and the incidence of five defects (mould, slate, weevil, germinated beans, and "other defects") which usually occur in West African cacao was determined. Results show that there is a marked lack of uniformity in quality and that the percentages of defects are higher than occur in plantation-produce. In some cases, defects vary in amount with the season, but in general they arise from inefficient methods of reaping, fermenting and drying.

Origin of defects.

It is necessary here to make a definite statement as to the origin of these defects. Slatiness is the result of inefficient fermentation, germinated beans occur in over-ripe pods or result from insufficient fermentation, and the class "other defects" is composed of undeveloped beans, fragments of placenta or mucilage, and foreign matter. These defects are definitely

attributable to the methods used by the farmer. Mould occurs on moist beans (8% moisture or over) and is nearly always the result of insufficient drying after fermentation. Weevil is a storage-defect and has been found both in farmers' lots and in merchants' stores.

Lack of organization.

Defects and lack of uniformity in produce are characteristic of unorganized peasant industry in any country and are not peculiar to the Gold Coast. The effective remedy is co–operative preparation and co–operative marketing, and it is applied in progressive countries by the private enterprise of the farmers themselves. It has been introduced into India, Ceylon, Mauritius and Malaya, and there is no apparent reason against its introduction and use locally. It cannot however be initiated and sustained in the Gold Coast without emphatic approval and support from Government.

Effect on London prices.

The effect of local methods of preparation and marketing on price are very evident. In 1926–27, London prices for Gold Coast cacao ranged from £55 to £77 10s., against £62 10s. to £87 10s. for San Thome and £65 to £87 for Grenada cacao of the same variety (Forastero) but prepared by standard plantation-methods and marketed in lots of adequate size. To abolish this difference it does not suffice merely to improve the quality. The industry must be organized in such a manner that the manufacturer can make contracts ahead with complete assurance as to good quality and uniformity. He must be able to cut out provision of special machinery and labour for reconditioning low-grade produce.

Effect on local prices.

The effect of individual preparation and marketing on local prices is even more serious. It is not possible for the merchant to deal individually with each of the thousands of small farmers, and in the absence of any other organisation he is obliged to work through lesser buyers and brokers. The farmer creates no fund individually or collectively to finance himself and a system of advances has grown up. In many cases the produce passes through two intermediaries, the petty itinerant buyer and the broker, before reaching the exporter. This system of centralisation is a wasteful one, but it is necessary so long as the farmer limits his exertions merely to reaping and preparation.

The merchant's task.

In 1927, the Committee on Agricultural Policy found (Sessional Paper XVII of 1927–28) that local prices quoted by merchants constituted a fair proportion of world's prices. The whole task of financing the crop, supervising every detail of collection, bagging, bulking, transport and shipment is left by the farmer to the merchant. The farmer demands spot-cash for each little lot of produce, while the calculation and assumption of risk of marketing is left to the merchant. During periods of wide fluctuations in world's prices, as for example 1928, losses to local firms have been severe. The risk, stress and expense of obtaining supplies under existing conditions are becoming very nearly intolerable.

Radical problem.

The whole series of local arrangements for preparation and marketing is unsatisfactory from the point of view of Government, both because there is increasing friction over questions of price and because quality is becoming more and more a factor determining prices in the world's markets. Other West African Governments have taken compulsory action in order to improve their positions, and similar action has been proposed locally during the past few years. In most cases, the measures adopted or proposed have aimed at standardisation of quality, but have not attacked the radical problem of the farmer's finances. It is probable that a finally effective scheme should aim at creation of funds with the purpose of overcoming tendencies towards hurried local sales.

A test case.

During the 1928–29 major crop, the Department of Agriculture made a planned attempt to form and operate a co-operative unit for preparing and marketing cacao. A group of seventy-eight farmers were persuaded to subscribe capital for erection of a common store. The store was of a capacity of 500 bags, was built of iron sheeting on a model prepared by the Department and cost £33. The Department erected a sun-drier near the store at a cost of about £30, and the farmers undertook to prepare their cacao by standard methods, to bulk it and sell it jointly. The Department supervised all operations, examined and certified the product. The first two lots analysed 98.7 and 98.6% purity (1.3 and 1.4% total defects). On the certificates, the group was able to sell direct to the merchant, cutting out all intermediate charges. The first lot sold at 2s. the second at 2s. 6d. per load (£3 14s. and £4 12s. 6d. per ton) above the local broker's price.

Further capitalization.

In operating this test-case, the Department was met by the difficulty that no fund existed from which farmers could be paid spot-cash for each small lot brought in. To overcome the tendency towards immediate sale, such a fund is necessary. The farmers were therefore advised to create their own capital fund (in shares of 1/– each), and in a fortnight they subscribed £160. It is intended to register this unit under the Co-operative Societies Ordinance with an authorized eventual capital of £500 in shilling shares. The fund will be used to finance members' needs during the inter-crop and to pay each member a proportion of the value of his lot of produce upon delivery during next major crop.

Benefits.

It is obvious that a scheme of this kind deserves and should obtain support from farmers, merchants, manufacturers and Government. It is effective in improving the quality of product turned out. It develops a spirit of self-help and mutual help among the farmers. It stabilises and improves the relations between farmers, merchants and Government. Finally, it is efficient in reducing waste of time and money. If the system can be made general for the whole industry there will be no need for compulsory measures excepting such as may be required by the people themselves for guiding and guarding their societies and work.

Size of primaries.

In any effective co-operative organisation, the first step is the formation of small primary units. The second step is the formation of larger secondary groups of units. Secondary groups should not be formed by fusion but by confederation of primaries. The point is a vital one, particularly in a country of illiterate, small peasant-farmers. The primary unit must be small enough for members to know each other intimately, and for methods of book-keeping and accounting to be simple. It is probable that, under local conditions, a primary of safe and convenient size would be one of not much more than 100 farmers or one handling not more than 100 tons of cacao. A group of this size should find little difficulty in subscribing £500 during the course of five years.

Federations.

The Co-operative Ordinance now in draft and ready for presentation to Council does not provide for secondary federations. The omission is intentional, since for many reasons it is unwise to form secondary

federations at too early a stage. Sound secondaries cannot arise excepting they rest on businesslike and stable component primaries, and one unstable primary may very easily wreck a federation. No insuperable difficulty of organisation arises, however, in grouping together a specified number of primaries by means of a central committee, and this further step is contemplated after a system of primary units has been thoroughly tested and consolidated.

Basis of agricultural banks.

Locally it has been assumed that an Agricultural Bank, entirely capitalized by Government or by some other body external to the farming community is necessary and would be beneficial. The idea is unsound for three reasons. In the first place, such an arrangement would hardly discourage thriftlessness, and might even foster it. Secondly, adequate security is not obtainable from individual small farmers under present local conditions. In the third place, no large central bank can hope to fill the petty, recurrent needs of individual small farmers. A sound and effective system of agricultural banking in a peasant country must grow from and rest on a network of small associations of individuals each of which knows its own business and handles its own business. In other words, primary societies fill petty personal needs, secondary federations handle joint needs, and groups of secondaries are real, living, effective banks.

External capital.

A characteristic of the co-operative system operated in Ceylon and India is that, under certain conditions and for specified objects, Government places funds as loans at the disposal of societies. The extent to which this will be necessary in the case of the marketing societies contemplated in this memorandum is not known with certainty. A primary unit handling 100 tons of cacao in a season can reasonably be expected to subscribe an eventual capital of £500. Assuming that members bring their cacao to the store in four lots, this capital would suffice for an advance of £20 per ton, or roughly two-thirds of the value. In addition, with punctual sales a considerable sum should always be in hand, since 25 tons are worth on the average some £750 locally.

Government loans.

Premature loans by Government to marketing societies would certainly lead to misunderstandings. They would be interpreted as a policy of financing the industry against local buyers. In addition, they would be risky, more risky than is justified where

public funds are involved. These criticisms do not apply where societies are of proved stability and soundness, since a loan then may be regarded as a reasonable investment of surplus public funds, just as proper and beneficial as an investment for municipal improvements. A convenient working-rule would be to require a certificate from the Director of Agriculture of the soundness of the society applying for the loan. The capital of the society should have been subscribed punctually, the society should have been operated wisely for three to five years, and the object of the loan should be rigidly defined. Loans in the first instance should not exceed paid-up capital, but later and in cases of proved efficiency could be twice or three times as large.

Supervision and control.

There are reasons for believing that the system considered here would grow rapidly, too rapidly for safety in the early stages. Very rigid, thoughtful control would have to be exercised by Government. If the scheme become a complete one, covering the whole cacao crop, the number of primary units would not be less than 1,500, and two lines of control would have to be established. Inspection and certification of produce would be performed by the Department Inspectorate, supervision of books and accounts by the Economics Division, and a staff of fair dimensions would be needed. Observation of the Nigerian up-country scheme of inspection (cotton, cacao, palm-oil and kernels) shows that the cost would not be prohibitive. The Nigerian scheme is financed by an export fee of 2/– to 2/6 per ton of produce.

## PAPER No. II.

# GEOGRAPHICAL DISTRIBUTION OF PRINCIPAL LOCAL CROPS.

By A. C. MILES.

In the accompanying map an attempt has been made to define more particularly the areas where crops exist in commercial quantities and are the principal occupation of the populace. It portrays more especially the location of crops yielding exportable produce, the one exception to this being rice areas in the Western Province of the Colony. In the latter case production is sufficient to exceed local demands and the surplus is disposed of outside the growing area. Apart from this one instance no attempt has been made to show production areas of crops for purely local consumption. As is well known, under ordinary normal circumstances, practically all rural areas are self-supporting in so far as supplies of agricultural produce are concerned. Such does not apply to the large towns, and mining areas, where the population is engaged in other than agricultural pursuits. In such cases supplies of agricultural produce are sent in from numerous and distant places, and to show the location of centres of crop production for this purpose would complicate the present object.

Previous attempts to illustrate the distribution have merely served to show where certain crops exist, or are grown, and have not defined the approximate areas in which crops are sufficiently abundant to be regarded as of commercial importance or potential value. Thus it must be understood that the map now submitted does not (*a*) show all the crops that are grown, (*b*) include all the products of value, or (*c*) illustrate the exact limits within which any crop is to be found. It aims at showing the areas occupied by the more important crops known to be of commercial value at the present time, and which are engaging the attention of the Department of Agriculture.

As might be expected cacao occupies the most important space on the map. In Trans-Volta the cacao areas appear to be surrounded by cotton. This is due to cacao being grown on the upper reaches, and hill tops, while cotton occupies the lowland.

In Western Central Ashanti the distinctive colour indicates the cola belt, i.e., that part of the country in which cola reaches its optimum. It is well known that cola appears in many other parts of the country and that the production is considerable in some localities,

but the area marked on the map shows the approximate limit within which cola is the crop of greatest importance. Some cacao is produced at most of the villages within the area, and this crop extends beyond the cola belt ; thus in the former case it gives way to cola, and in the latter the position is reversed.

With respect to the oil palm area a similar explanation should suffice. The Northern limit of the palm belt is taken as being the point at which cacao can be grown successfully and where this crop has been given preference to the older indigenous one. It may be assumed that this change is directly attributable to the introduced crop having proved the more profitable. Along the Northern limit of the cacao area the oil palm appears in a more or less irregular belt of variable density, but is not in sufficient quantities to be regarded as suitable for commercial development on modern lines. It may be possible at a later date to establish small mills in such areas, to produce supplies to meet local demands for culinary purposes.

The cotton area outlined around Tamale indicates what is regarded as the most suitable locality within economic reach of the ginnery erected at Tamale last year. Within the area shewn there is a good system of roads, numerous villages fairly well populated, and conditions generally are suited to cotton growing. Propaganda work in connection with the crop is for the present to be limited to this area. As will be seen, it is surrounded by the Shea area and Shea is distributed all through it, but since attention is being focussed on the production of cotton for export the latter crop only is figured.

Shea trees are to be found in most parts of the Northern Territories, but the shading indicates the richest area. The extension south of Tamale to Salaga may be less rich than other portions but on account of being much nearer to rail-head it is regarded as being of equal value since the cost of transporting the product would be appreciably less.

Coconut palms are to be seen at most villages along the littoral but the produce from these palms is for the most part disposed of while immature and in the green state, for local consumption. The Keta-Ada area illustrated produces copra for export, and it is the industry of the District. At Labadi in the Eastern Province, Cape Coast in the Central Province, and Atwabo in the Western Province, the Department has established Coconut Plantations and copra is being produced, the object being to encourage the industry at all suitable places along the coast.

Lime cultivation in the Abura Division of the Cape Coast District, may be regarded as an established industry, and arrangements are now in being to erect a factory at Abakrampa. The representative of a reputable and well known firm of Lime Juice manufacturers has recently visited the area, and being favourably impressed has recommended his company to establish a factory in the locality.

No attempt has been made to show the distribution of rubber, as of late years the collecting of indigenous rubbers has almost ceased. Small quantities of Funtumia, Paste, and Ball rubbers figure in the exports and the major portion of these come from Ashanti. The increased exports in 1925 and 1926 were largely due to the production of Para rubber from plantations.

The following list shows exports of products referred to herein during the past five years :—

| Products. | Total Exports. | 1923 | 1924 | 1925 | 1926 | 1927 |
|---|---|---|---|---|---|---|
| Cacao .. .. | .. Tons | 197,644 | 223,329 | 218,151 | 230,840 | 209,910 |
| Cola .. .. | .. ,, | 6,097 | 7,773 | 6,097 | 5,569 | 5,128 |
| Palm Kernels .. | .. ,, | 3,757 | 6,592 | 6,569 | 7,659 | 6,545 |
| Palm Oil .. | .. ,, | 1,520 | 1,350 | 1,423 | 1,752 | 1,090 |
| Copra .. .. | .. ,, | 1,660 | 1,163 | 1,324 | 1,513 | 1,454 |
| Shea Nuts .. | .. ,, | — | — | — | 50 | 37 |
| Rubber .. | .. lbs. | 312,922 | 272,182 | 1,097,832 | 1,418,250 | 711,288 |
| Cotton .. .. | .. ,, | 37,114 | 5,982 | 4,416 | 20,203 | 116 |

In addition to the exports of cola shown above, the average annual quantity recorded at Ferries (on the *route* to the North) is 1,650 tons for the years, 1923 to 1927.

# DEPARTMENT OF AGRICULTURE

## DISTRIBUTION OF PRINCIPAL COMMERCIAL CROPS 1928.

1/A/28

Survey H.Q. Accra. 1928.

PAPER No. III.

# THE INSPECTION AND CERTIFICATION OF AGRICULTURAL PRODUCE.

By A. B. CULHAM.

In these days of mass production or manufacture of commodities, irregularity of the raw material is a serious depreciating factor in the value of that material. So true is this that a superior article has a poor chance of receiving a premium in price over an inferior article of standard grade—that is a grade which buyers and manufacturers know and have arrangements to deal with—unless that superior material comes forward in sufficient quantities to make it economically possible for the buyer to handle it and the manufacturer to use it as such. In so far as the exclusion or elimination of impurities is concerned this applies only in a limited degree, but the provision of standard materials, the value of which shall be appraised on standard lines is the desideratum of modern industry.

Taking for an example a product of extreme inferiority and irregularity it appears obvious that the first disability to be eliminated is the inferiority. By inferiority is meant a quality inferior to one reasonably attainable. When the product reaches a reasonable standard of cleanliness and freedom from extraneous defects, then the irregularity fails to be dealt with. It may be possible to carry on both processes at the same time but generally it will be found that standardisation is a later step.

Even in the most modern and civilised of productions no two producers will or can produce an identical article. Both may be good but they are not the same. Anyone required to use both simultaneously or even alternately has to make special provision for the weaknesses of, or, economically to use the article, has to know the extent to which he may stress the good qualities. Therefore the necessarily combined product of many producers suffers according to its lack of uniformity.

This is particularly noticeable in raw materials where in most cases the combined products of many producers is utilised by one manufacturer and it becomes an extremely serious factor when the product contains material of a widely differing quality. In

the case of uncontrolled production, the larger the number of independent individuals concerned in the production, the greater the possibility of divergence from the mean. To no industry is this rule more applicable than uncontrolled peasant agriculture, and it is natural that ignorant producers should take no steps to improve a product which already sells readily at considerable profit, even assuming their capacity to do so.

When a product is used by a large number of small concerns, as is the case of local food crops, the necessity for standardisation does not appear. It is only when individual productions have to be bulked for the use of one large consumer that it arises. Large individual consumers of tropical agricultural products are usually situated outside the country of production, therefore in practice it is only produce for export that has usually to be considered in the tropics. In the Gold Coast and British West Africa in general the problem reaches its most acute form. Almost the whole of the agricultural production is by individual indigenous farmers. The cacao export, for instance, is the combined output of something approaching 200,000 farmers. It is a product used by a relatively small number of manufacturing firms, and owing to the extreme variation due to the number of producers is not so well suited to their needs as the output of countries where production is in the hands of a smaller number of large concerns usually managed by Europeans, who can deliver a standard product of good quality. Hence it invariably obtains a lower price than the standardised product and, economically, the situation is unsatisfactory.

That the improvement of quality and standardisation of export agricultural produce in British West Africa is necessary to secure the full reward for agricultural industry is no new idea. The difficulty has lain in its effectuation by a process of inspection, and each Colony has approached the problem in a manner suited to the present needs and facilities of that Colony. In Sierra Leone and Nigeria the submission of certain agricultural export products to inspection is now compulsory. On the Gold Coast there is an inspection of cacao which is voluntary. It may be stated here that the Gold Coast system being voluntary has no effect on the actual volume of cacao examined as there are no objectors. Where the difference lies between the compulsory system and the voluntary one is that there are no restrictions and penalties in the latter case. It relies entirely in so far as improvement is concerned on education and inducement.

That the system is voluntary is largely a result of the unwillingness of the industry to support or submit to any compulsory scheme. There was a proposal to license buyers which met with strong opposition and was abandoned. Another system proposed was that of registered buying centres. Under this scheme it was proposed to limit the sale of cacao to certain centres where

the cacao was to be inspected. This met with a like fate largely on account of possible hardship to producers in compelling them to transport produce considerable and unnecessary distances and its supposed impracticability in other directions. A voluntary system based on a differential export duty according to quality was also suggested but advanced little beyond that. In the year 1924 a Government consultation with exporters resulted in practically unanimous opposition to any form of inspection being registered and it was only in January, 1927 as a result of the continued and heavy rejections of consignments of Gold Coast cacao by the United States of America, that shippers agreed to permit of the inspection by Government of cacao exports at ports. It was undertaken purely as an investigation for one year only. However, the permission of exporters was obtained to a continuation and after two years' work the Gold Coast is in possession of full and accurate data as to the quality of cacao exported.

Out of this investigation a system of reports to shippers has arisen. A report on the samples taken from each consignment is issued to the shipper and the reports are now regarded by shippers as valuable as an unbiased opinion on the consignment as it left the country. An authoritative statement as to the condition of the cacao on shipment must have an important bearing on the responsibility of the shipper, particularly in the matter of insurance.

The methods of inspection are based on those used in the United States of America, in that a number of samples is taken equal to the square root of the number of bags in the consignment. Very careful and exhaustive experiments have been made to test the accuracy of the method (*see* Paper No. VI Year-Book 1927) and it may be taken that it produces a result as near to absolute accuracy as any practicable method of sampling cacao at Gold Coast ports can be. Whilst on the subject of sampling methods it may be stated that satisfactory methods of sampling copra and palm kernels have been worked out recently and will be published.

Whilst port inspection of cacao has had a good effect on quality in that it has placed the shipper in possession of accurate knowledge regarding the quality of cacao he is shipping—only 105 bags of Gold Coast cacao were rejected by the United States authorities in the year ended September 30th, 1928 as against 93 bags Nigerian and 4,368 African unclassified—there is still no sufficiently marked inducement for a farmer to take special, or even ordinary, pains to prepare his produce to the best of his ability. The cry is now as always, " no better price for better cacao."

An attempt was made to remedy this in the 1928–29 season by instituting a system of up-country certification. The system was simple and voluntary. In certain areas where the scheme was put into force a farmer could obtain the services of an agricultural

officer to examine the cacao he had for sale. After examination the bags containing the cacao were sealed and a certificate issued. The farmer could then sell his on the certificate to any buyer he wished. Several firms promised and actually gave premia on the price paid for such parcels but at the meeting of the Cacao Advisory Committee which consists of representative European and African merchants and paramount chiefs, the scheme was disapproved of and on this advice the Government did not proceed further with the scheme.

The cost of inspection has so far been borne by the general revenue of the Colony but the question of an inspection fee to cover the cost has not escaped attention. The essential difference is that in the former case the whole of the community bears the cost whereas in the latter it would be borne by the cacao producer. In Nigeria an inspection fee of 2s. 6d. per ton is collected on export. There is something to be said for both systems, but it is not at present proposed to change in the Gold Coast that now in force. It may be assumed that in a case where almost the whole population would benefit by the improvement of export agricultural produce any cost of such improvement can fairly be borne by general revenue. Such a case applies to the Gold Coast.

Proposals are now on foot to combine the inspection of cacao up-country with the co-operative movement which is being fostered. There is good reason to suppose that this attempt will be successful as a cacao growers' association already in existence has obtained a premium of 2s. 6d. per load of 60 lbs. on cacao sold in the 1928–29 season. The cacao was prepared entirely by the farmers themselves, the Department of Agriculture merely acting in an advisory capacity. The essential thing for such a co-operative society is a good building in which the individual farmer's lots can be collected and stored until a sufficient quantity has been collected to enable buyers to treat it as a separate parcel. It is impossible for buyers to pay a reasonable premium unless such a quantity is available. Individual small lots go in with the ordinary bulk of cacao bought and cannot receive a preferential price.

All inspection of cacao on the Gold Coast has been in the nature of investigation and certification. By certification is meant the issue of a certificate of quality after examination. In port inspection there is no attempt at grading but if standardisation is to be obtained this will have to be done and up-country inspection should include some form of it. Nigeria has four grades. It is not proposed to have at present any system of fixed grades in the Gold Coast at first, but to issue a certificate of quality to all co-operatively sold cacao above a certain standard, which may vary in different centres. The cacao will not be

certified as of any particular grade but the buyer will be in a position to know from the certificate the exact quality of the cacao he is buying. It was stated at the meeting of the Cacao Advisory Committee referred to above that some buyers prefer to trust their own judgment but, be this as it may, a certificate of quality issued by a competent authority cannot fail to be of value. It has been found in Nigeria that merchants—as opposed to manufacturing buyers—are content to accept the assurance of the Produce Inspectorate that the produce is actually of the stated quality.

In the standardisation of West African cacao there is much to be done. In so far as export to the United States of America is concerned the Food Law limitations of 10% mouldy or 15% mouldy and wormy form the standard at which the exporter has to aim. England has a system of grades based on the percentage of slaty and otherwise defective beans. The position which the underfermented bean, as opposed to the unfermented bean occupies in the grade is uncertain. Accepted standards are required by which the position of all defects and the degree of fermentation are defined in such a way that personal error in determination of quality is reduced to an absolute minimum. Then only will it be possible for dealers in West African cacao at home and abroad to be certain of what they are buying or selling. Given these standards, by a system of grading it would be possible for the irregular product of a peasant industry to be placed on the market in a form, or in forms, which would meet the specific requirements of manufacturers thereby cutting out the present uncertainty and the frequent occurrence of disputes, and placing the industry in a position to compete with the more regular products of other countries.

PAPER No. IV.

# APPLICATIONS OF THE CO-OPERATIVE SYSTEM TO LOCAL AGRICULTURE.

By A. W. PATERSON.

The first point that naturally arises in considering the question of the application of the Co-operative system to local agriculture is whether the local African farmer has any inclination to work with his neighbours for the common welfare. The aboriginal organisation appears to have rested on a communal basis; land was owned by the community and administered by the Chiefs and Elders who were elected by the people. Work for the general benefit such as the building of a system of roads was carried out by communal labour. Palm oil, in the past was, and, where still manufactured, is, produced communally and in many parts of the country the farmers still combine to clear new farms and harvest their cacao crops in rotation.

The next point to be considered is in what ways co-operative societies can benefit the local system of peasant farming. There appear to be two obvious directions in which such a system would assist local farmers. Firstly by the accumulation of funds, raised by contributions from the members, which could be advanced to necessitous individuals amongst members. These funds could also be utilised to erect small stores for the collection of the members' produce for sale co-operatively.

The defects of a peasant agricultural industry are :—

(*a*) The irregular quality of the produce.

(*b*) The disadvantages of having to offer small lots of produce to the markets.

(*c*) The lack of capital for effecting improvements in methods of cultivation and preparation.

(*d*) The necessity of immediate sale of produce.

The disadvantages of the present buying system are :—

(*a*) The elaborate and expensive organisation required by exporters for centralising the sale of produce.

(*b*) Capital advanced by exporters to buyers of doubtful financial stability.

(*c*) The difficulty of estimating stocks in a fluctuating market.

(*d*) Waste of labour in further drying of damp cacao.

(*e*) The resulting necessity for employing middlemen.

(*f*) Money-lending against the cacao crop.

It would appear from the above defects in the cacao industry that there is ample scope for improvement and that any movements which would bring the farmer and the exporter into better mutual relation would be welcomed by both parties. It seems reasonable to accept that some of these disadvantages can be overcome by grouping producers into societies which will be pledged:—

(*a*) to standardise the preparation and quality of their produce,

(*b*) to operate as a body rather than to sell individually.

There have been attempts made by groups of farmers to market their cacao in bulk, but the majority of these were foredoomed to failure in the absence of any controlling ordinance. In some cases, however, groups of farmers have sold to local exporters with satisfactory results and the number of these societies is increasing. For example in the Krobo Plantations the farmers of Jumoa and Sitrisu were successful last season and this year the neighbouring villages of Odumetta and Asesawa are following suit. These groups have this season made agreements for the sale of their produce in bulk with local firms on favourable terms. At Atasamanso, in Ashanti, the farmers have joined together and regularly sell their produce in bulk at a very considerable premium. The Nsawam-Aburi Cacao Growers' Association was founded in 1919 and although it has had many vicissitudes it still survives and markets its cacao in bulk to the satisfaction of its members.

At Abokobi, near the base of the Aburi Hill, there is a very interesting society of a different kind. In this case we have a body of farmers who united together to farm co-operatively. Each member contributed 5s. as an entrance-fee and agreed to work one day each week in the Society's farm or pay the sum of 1s. 6d. for each day missed. Each attendance or payment in lieu thereof is credited to the person's account and if any interest or profit is ever to be disbursed it would be in the ratio of the amounts so contributed. All produce is sold, members having preference both as regards prices and option for their own needs only, the Society receiving all proceeds. All profits up to the present have been devoted to the purchase of European fowls, wire netting and a motor lorry to convey the Society's produce to Accra Market and for local hire. The land originally utilised belonged to the Scottish Mission who granted the use of it free but additional land has since been purchased and to do this a levy of £2 per member was made.

From the foregoing it would appear that with a Co-operative Societies Ordinance, such as has been adopted by Government, the position of these Societies would be consolidated and put on a sound financial basis. The books of each registered Society would require to be audited at least once a year by officers appointed by the Registrar of Co-operative Societies who is empowered moreover to call for all the books of a Society either on his own right or on demand by a majority of the Committee or one third of the members of the Society. Wrongful use of the funds of a Society can be severely punished.

In order to gain local experience in the handling of such Societies and of the general methods of running such organisations a thrift society was formed in Accra, amongst the Head Office staff in March, 1928. A similar organisation has been founded at the Agricultural and Forestry Training Centre, Kumasi, amongst the pupils and staff and is making satisfactory progress.

PAPER No. V

# CURVE OF INCREASE OF CACAO PRODUCTION LOCALLY AS A MEANS OF FORECASTING THE MAGNITUDE OF THE CROP.

By A. C. MILES and J. C. MUIR.

Much has been written in the past about the romantic development of the cacao industry in the Gold Coast and no doubt similar references will be made to it for some years to come. The object of this paper is, however, to avoid the romantic and to review the subject from a commercial aspect, based on such data as can be obtained from the official " Blue Book " and to review the annual exports over a period of twenty-two years, in comparison with data available from Experiment Stations.

## AFRICAN PEASANT GROWERS RESPONSIBLE FOR INCREASED PRODUCTION.

The increase in production has been little short of marvellous, and it is the more remarkable that such progress should have been made in an industry which, so far as production is concerned, is almost exclusively in the hands of African peasant growers. As proof of the former, we find on reference to the Blue Book that in 1906 the total exports of cacao were 8,975 tons, whereas in 1926 the exports had leapt to the total of 230,840 tons, a total increase of 2,572% during a period of 21 years. 230,840 tons has so far proved the pinnacle of production, the exports for 1927 being 20,930 tons below that of the previous year. While admitting that a decrease of this amount appears somewhat serious, being more than our total output for 1909, it is of less real importance than the figures suggest, as will be explained later.

## CURVE SHOWING INCREASE IN EXPORTS.

In the accompanying graph annual exports are shown from 1906–1928 inclusive, together with the curve obtained by grouping the annual exports in periods of five years; the curve being smoothed by using an overlap of four years.

Examination of the curve will show that there is a tendency towards a flattening out during the period 1924–28.

## ECONOMIC REASONS FOR VARIATION IN ANNUAL EXPORTS.

A study of the graph shows a steady increase in exports for the period 1906–15, except for a slight temporary set back in 1912,

probably due to climatic factors. Limited shipping facilities as a consequence of the European War resulted in a decrease in exports in 1916 but this was off-set by an increase of 18,000 tons in 1917 ; cacao being in demand as a source of fats.

In 1918 an acute shortage of shipping was again the cause of a drop in exports, the tonnage falling short of the 1917 exports by 24,000 tons.

Following the Armistice and the release of shipping, together with a trade boom in 1919, exports for that year bounded to 176,000 tons, an increase of 110,000 tons over the previous year. The above figures refer only to exports, and it is not claimed that actual production had increased to the same extent ; indeed it is evident that a considerable proportion of the cacao exported that year was an accumulation of old stocks, as is proved by what happened during the following year. Record prices obtained during 1920, and there are good reasons for supposing that the exports of 124,000 tons during 1920 represented the approximate crop for that year.

From 1920 to 1924 there was again a steady increase in production, followed by a slight set-back in 1925, when exports dropped by 5,000 tons.

The total of 230,000 tons which remains our record output, was produced in 1926, the exports for 1927 falling short of that total by 21,000 tons.

## EXTENSION OF AREA UNDER CACAO IN RELATION TO INCREASED EXPORTS.

From 1906 to 1915 the rise in exports was steady and planting of new cacao farms was proceeding apace. From 1915 and during the period of depression brought about by the World War, little if any planting was being done. Meantime established cacao plantations were neglected and in distant localities the crop was not collected during 1917–18 and 19.

The improvement in cacao values during the latter part of 1919 and 1920 gave a new impetus to planting, which has been maintained by improved communications, and reduced transport rates. The results of these new areas coming into bearing is first shown in 1923 and continues to be apparent.

## TREND OF CURVE SHOWING CACAO EXPORTS.

The curve denoting trend of exports shows no appreciable variation until the year 1924, when there appears a tendency towards a flattening out of the curve which is suggestive of an approaching maximum output, and makes the period 1923–27, worthy of special attention.

The mean annual exports during those five years were 216,000 tons, thus it will be seen that a deviation of 8% is sufficient to account for variations in annual exports during the period. It is this knowledge which prompts the statement, at the conclusion of the second paragraph ; that the decrease in exports during 1927 was of less importance than the figures suggest at first glance, since the deviation from the mean exports for the period 1923–27 was but 2.77%.

## INFLUENCE OF CLIMATIC FACTORS ON PRODUCTION AND EXPORTS.

The influence of climatic factors on the yield of cacao is important, and causes annual variations of considerable magnitude. Having obtained the figure quoted in the preceding paragraph, reference was made to the records of plots on the Experiment Stations at Kumasi, Asuansi, Aburi and Kibi. It was found that for the same period (1923–27) deviations from the mean yields were as follows : ± 16%, ± 25%, ± 18%, and ± 28% for the Stations in the order named.

## RANGE OF VARIATIONS OVER A LONGER PERIOD IN HIGH YIELDING AREAS.

For the period 1911 to 1927, namely 17 years, the percentage deviation from the mean yield of cacao in plots at Aburi is ± 50% as against ± 18% for the five years period 1923–27. The larger deviation in the longer period is due to the initial high yields, which persisted during the early fruiting period for seven or eight years, after which yields declined to a lower but less variable mean. It is improbable that these enormous deviations from the mean take place in the lower yielding areas, such as those bordering the northern extremity of the cacao belt ; and this theory is supported by recorded yields of plots at the Kumasi Experiment Station, which show that over a period of ten years deviations from the mean were ± 18% ; but in all probability they do obtain over the greater part of the cacao areas existing under relatively similar conditions to those at Aburi.

## INDICATIONS OF APPROACHING MAXIMUM EXPORTS.

There is already much cacao established in areas where it is not likely to have a longer economic life than 10 to 20 years. On the other hand there is a vast area of first class cacao land untouched in the Western Province, but the country is undeveloped and, being sparsely populated, many years must elapse before this area contributes quantities sufficiently large to have any appreciable effect on annual exports. It is felt, however, that its development may

serve to maintain output at least comparable to the mean annual exports of the past five years, it is thought that exports are approaching the maximum. It is not suggested that the peak of production will be reached this year or next, but it is evident the rate of increase cannot continue indefinitely, even if the world demand were such as to consume the output.

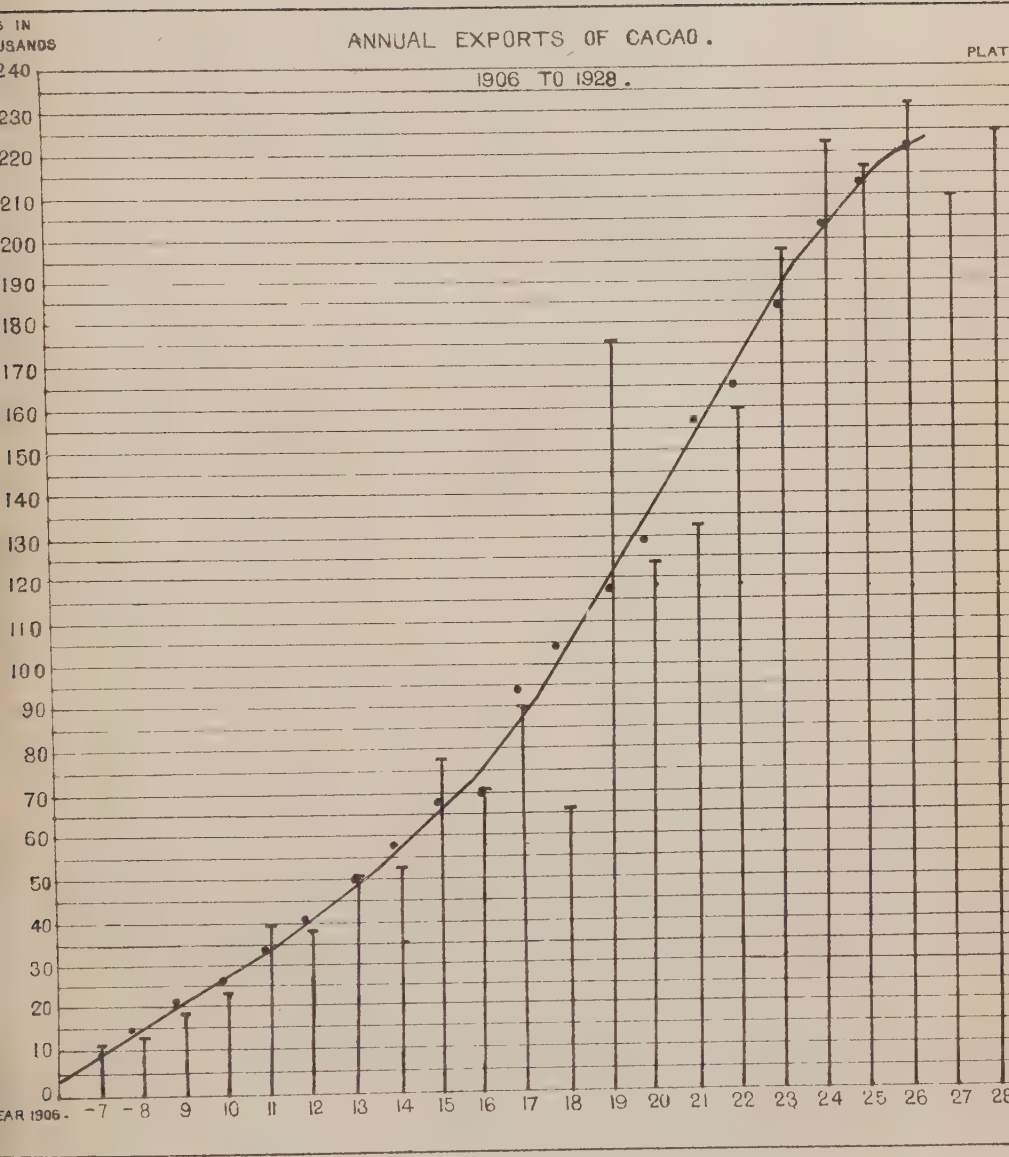
Having shown the magnitude of the deviations from the mean yield which occur in four widely separated areas, it is not suggested that the yield of the cacao belt taken as a whole will be subject to such large variations ; but it is thought that while the mean export, ± 8%, is sufficient to account for annual variations in tonnage over a period of five years, we are not yet getting the produce of what may be regarded as a constant area. In other words, the initial high yields of young plots, together with new areas coming into bearing each year, are sufficient to balance the yields from those areas dropping from their period of high to their period of moderate productivity, and to maintain our exports in a comparatively stable condition.

**Tons of Cacao Exported Annually during period 1906–1927.**

*Copied from Blue Book.*

| Annual Exports. | | Mean Annual Exports (5 year periods) | |
|---|---|---|---|
| 1906 | 8,975 | 1906/10 | 14,784 |
| 1907 | 9,356 | 1907/11 | 20,934 |
| 1908 | 12,744 | | |
| 1909 | 20,213 | 1908/12 | 26,792 |
| 1910 | 22,631 | 1909/13 | 34,354 |
| 1911 | 39,726 | 1910/14 | 40,889 |
| 1912 | 38,647 | 1911/15 | 51,819 |
| 1913 | 50,554 | 1912/16 | 58,306 |
| 1914 | 52,888 | 1913/17 | 68,769 |
| 1915 | 77,278 | 1914/18 | 71,927 |
| 1916 | 72,161 | 1915/19 | 96,584 |
| 1917 | 90,964 | | |
| 1918 | 66,343 | 1916/20 | 106,083 |
| 1919 | 176,176 | 1917/21 | 118,290 |
| 1920 | 124,773 | | |
| 1921 | 133,195 | 1918/22 | 131,958 |
| 1922 | 159,305 | 1919/23 | 158,222 |
| 1923 | 197,664 | 1920/24 | 167,653 |
| 1924 | 223,329 | 1921/25 | 186,329 |
| 1925 | 218,151 | 1922/26 | 205,858 |
| 1926 | 230,840 | 1923/27 | 215,979 |
| 1927 | 209,910 | | |
| 1928 | 225,077 | 1924/28 | 221,461 |

# PLATE. II.




VERTICAL LINES REPRESENT EXPORTS OF INDIVIDUAL YEARS.
BLACK DOTS SHOW MEANS OF 5 YEAR PERIODS WITH OVERLAP OF 4 YE
BLACK CURVE SHOWS GENERAL TREND OF INCREASE.

Survey H. Q. A

## PAPER No. VI.

# PROVISIONAL MAP SHEWING DISTRIBUTION AND EXPORTS OF CACAO IN 1927.

By G. G. AUCHINLECK and N. P. CHAMNEY.

Conventional symbols.

In preparing the appended map, the convention has been adopted of representing each lot of 100 tons of exported cacao by a dot. Each dot or unit-symbol of 100 tons represented in 1927 an export value of about £5,000 and an area of production of about 400 acres of actual cacao-farms.

Red dots railway borne.

In the case of cacao which was carried to the ports by railway, red dots have been used, and, to accord with this convention, the railway-line and stations are shown in red. An exception to this rule has been made in the case of the cacao (4,842 tons) which crossed the French border to Palime and which eventually was transported by railway to the port of Lome in French Togoland. To avoid confusion with traffic on the Gold Coast railways, the Palime exports have been represented by green dots as lorry-borne.

Green dots lorry-borne.

Cacao which arrived at the ports by means other than railway transport is represented by green dots. With the probable exception of small lots of cacao which appear to have been water-borne on the Tano and Volta rivers to Half Assini and Ada, the green dots represent motor lorry-borne cacao.

Feeder-traffic to railway shewn red.

It should be understood clearly that the only lorry-borne cacao shewn in green on the map is that which actually arrived at the ports by lorry. The immense lorry-traffic along feeder-roads to railway stations is shewn in red, since it eventually reached the points of export by rail. The map therefore shews graphically the relative importance in 1927 of the two types of transport to the coast.

## RELATIVE SCALES OF MAP AND SYMBOLS.

Mechanical errors of scale.

Before proceeding to a consideration of the statistical figures upon which the compilation of the map was based, it is necessary to determine the difference in scale between the map and the spots employed to symbolise the groups of 100 tons of cacao. For purely mechanical reasons, it is not possible to make the area of a dot exactly conformable to the scale of the map, and the degree of distortion should be determined as far as possible.

Scale of the Map.

The scale of the map is 1 : 2,000,000, so that a linear inch represents 31.57 miles. A square inch therefore represents 997 square miles, or 638,080 acres, taking a ratio of 640 acres to the square mile. (The total area of cacao-farms in the Gold Coast is estimated to be 940,000 acres, which area could therefore be massed into about one and a third square inches of a map of this scale).

Area covered by a dot

The dots used in the map are about one-fortieth of a linear inch in diameter. The area of a circular dot of this diameter is $(3.14 \times (\frac{1}{(2 \times 40)})^2$ or .0005 of a square inch, so that 2,000 dots have an area of one square inch, representing on the map an area of 638,080 acres. One dot therefore covers an area of the map which is equivalent to 319.0 acres. The distortion of scale is therefore small, since 100 tons of cacao, at an average yield of 5 cwts. per acre, are derived from 400 acres of farm.

## EXPORTS OF CACAO IN 1927.

Customs figures of exports.

The figures of export on which the map is based were supplied by the Customs Department, and are for the calendar year January to December, 1927 :—

| Port. | Tons of cacao exported. |
|---|---|
| Half Assini .. .. .. | 581 |
| Axim .. .. .. | 52 |
| Sekondi .. .. .. | 66,117 |
| Cape Coast .. .. | 5,533 |
| Saltpond .. .. .. | 13,812 |
| Winneba .. .. .. | 20,518 |
| Accra .. .. .. | 98,778 |
| Ada .. .. .. | 610 |
| Palime (for Lome) .. .. | 4,842 |
| Total .. .. | 210,843 |

The total number of red and green dots on the map is therefore 2,108.

## CACAO RAIL-BORNE TO PORTS.

Traffic at Railway Stations.

The amount of cacao loaded at each railway station during the calendar year 1927 was obtained from the records of the Railway Department. The figures are given in the table below. In preparing the map from these figures, it has been assumed that all the cacao loaded at railway stations reached the ports by rail. Probably the total amount of cacao merely taken from one station and subsequently transferred to lorries at another station is negligible, but this point should be definitely cleared up later.

### Cacao Loaded at Railway Stations 1927.

*Eastern Province.*
(Stations from South to North).

| | |
|---|---|
| Nsawam | 18,451 |
| Pakro | 3,295 |
| Mangoase | 8,223 |
| Koforidua | 17,433 |
| Jumapo | 514 |
| Tafo | 3,594 |
| Bosuso | 692 |
| Osino | 527 |
| Anyinam | 2,104 |
| Kankang | 146 |
| Jyajate | 22 |
| Asuboni | 3 |
| Nkawkaw | 4,453 |
| Akwaseho | 238 |
| Kwahu Prahsu | 460 |
| Total E.P. | 60,155 |

*Central Province.*
(Stations from West to East).

| | |
|---|---|
| Damang | 7 |
| Subira | 12 |
| Ataku | 164 |
| Nyenase | 954 |
| Twifu | 733 |
| Ongira | 0 |
| Fosu | 143 |
| Akenkawim | 10 |
| Aperadi | 258 |
| Akeasi | 0 |
| Oda | 0 |
| Wanki | 1 |
| Kade | 54 |
| Total C.P. | 2,336 |

*Western Province.*
(Stations from South to North).

| | |
|---|---|
| Inchaban | 0 |
| Angu | 94 |
| Mansu | 61 |
| Bensu | 6 |
| Essuasu | 5 |
| Insuta | 9 |
| Tarkwa | 725 |
| Akantanse | 0 |
| Hunisu | 2 |
| Awudua | 5 |
| Ancobra | 240 |
| Prestea | 32 |
| Abosso | 75 |
| Huni Valley | 136 |
| Kuranti | 33 |
| Insu | 176 |
| Opon Valley | 424 |
| Oponsu | 109 |
| Imbraim | 87 |
| Buabin | 89 |
| Dunkwa | 7,233 |
| Total W.P. | 9,541 |

*Ashanti.*
(Stations from Southwest to Southeast).

| | |
|---|---|
| Ampuyasi | 67 |
| Jum Abufru | 656 |
| Obuasi | 954 |
| Akrokerri | 4,525 |
| Bekwai | 12,290 |
| Eduadin | 204 |
| Kumasi | 30 344 |
| Fumesa | 96 |
| Ejisu | 4,998 |
| Boankra | 419 |
| Wiresu | 21 |
| Bomfa | 1,260 |
| Konongo | 2,588 |
| Juaso | 1,089 |
| Bompata | 597 |
| Prah River | 449 |
| Total Ashanti | 60,557 |

To summarize this table, the total of railway-borne cacao in 1927 was :—

| | *Tons.* |
|---|---|
| Eastern Province Railway stations | 60,155 |
| Western Province ,, ,, | 9,541 |
| Central Province ,, ,, | 2,336 |
| Ashanti ,, ,, | 60,557 |
| Total .. .. | 132,589 |

Distribution to ports.

This total amounts to 62.9% of the total exports of cacao from the country.

The sole outlet for the railway-borne cacao loaded at stations in the Western and Central Provinces is Sekondi, and the Ashanti stations on the Western railway presumably delivered their cacao to this port. A certain amount of Ashanti cacao, however, went down the Eastern railway as the following figures show :—

**Sekondi Exports of Cacao (all rails) 66,117 Tons.**

| | |
|---|---|
| From Western Provnce stations .. | 9,541 |
| ,, Central Province ,, .. | 2,336 |
| ,, Ashanti ,, .. | 54,240 |
| | 66,117 |

**Accra Exports of rail-borne Cacao.**

| | |
|---|---|
| From Eastern Province Stations .. | 60,155 |
| Balance (surplus from Ashanti Stations) .. .. .. .. | 6,317 |
| | 66,472 |

In addition to the rail-borne cacao, Accra shipped 98,778–66,472 or 32,306 tons which presumably came by lorry.

## TRAFFIC TO PORTS BY MOTOR-LORRY.

Lorry and river traffic.

The difference between the figures of total export of cacao and the figures of rail-traffic is (210,843–132,589) or 78,254 tons, equal to 37.1% of the total amount exported. The amount is made up as follows :—

| | *Tons.* |
|---|---|
| Exports to Palime .. .. .. | 4,842 |
| Exports of Ada, Axim and Half Assini .. .. .. .. | 1,243 |
| Total of Central Province ports .. | 39,863 |
| Sekondi .. .. .. .. | nil |
| Balance (proportion of Accra Exports) .. .. .. .. | 32,306 |
| Total .. .. | 78,254 |

The exports from Half Assini and Ada (1,191 tons) were probably water-borne to port, and the remainder (77,063 tons) lorry-borne. There are no railways to Cape Coast, Saltpond and Winneba, and no feeder-roads to Sekondi from cacao-producing areas.

Declaration of stocks held needed.

It is necessary to point out that no account has been taken of cacao in stock at the end of the year. If stocks were held up-country, the export figures would be below the figures for actual production of cacao during the year. If stocks shipped by rail were held at the ports, the figures for apparent lorry-traffic (obtained by difference) would be less by the amount of such stocks. If the stocks held had been lorry-borne to ports, the total export figures would be below those of actual production. It will probably never be possible to obtain exact figures for stocks held back by farmers. Most of the stocks however are usually held by exporting firms, who should be asked to supply statements (confidential if necessary) of their stocks remaining unexported on December 31st.

## PRODUCTION CENTRES OF RAILWAY-BORNE CACAO.

Minor production centres.

The total number of railway-stations considered is 65 (Eastern Province 15, Western Province 21, Central Province railway 13, Ashanti 16). Of these there are 59 of comparatively minor importance individually, although their total cacao traffic in 1927 amounted to 38,615 tons, or 29.1% of the total rail-borne cacao of the country. The farm-area necessary to produce this amount must be about 154,000 acres (assuming a mean yield of 5 cwts. per acre). The production-areas which feed these stations probably lie close to the stations, and they have been so shown on the map, but the true distribution is not known with certainty.

Major production centres.

The six remaining railway-stations are of overwhelming importance. Nsawam, Mangoase, Koforidua, Kumasi, Bekwai and Dunkwa in 1927 loaded on the railway 93,974 tons of cacao, or 70.9% of the total railway-borne cacao of the country. The farm-area necessary to supply this amount must be about 450,000 acres. The distribution and relative importance of the production-centres which feed these stations are not known with certainty and exactness. The following apportionments, in most cases almost purely assumptions, have been made in compiling the map.

| *Production Areas.* | *Railway-borne cacao allotted to each centre on map (tons).* | |
|---|---|---|
| *Nsawam-Mangoase.* | | |
| East of railway .. .. .. | 10000 | |
| West of railway .. .. .. | 16,674 | |
| | | 26,674 |
| *Koforidua.* | | |
| Bisa area .. .. .. .. | 15,000 | |
| Round Station .. .. .. | 2,433 | |
| | | 17,433 |
| *Kumasi.* | | |
| Pamu-Sunyani-Goaso area .. | 1,500 | |
| Wenchi-Kintampo area .. .. | 300 | |
| (Bechem to Kumasi) .. .. | 8,500 | |
| (Nkawa-Kuma) Kumasi.. .. | 6,000 | |
| (Kobreso-Kumasi) .. .. | 9,000 | |
| East and South .. .. .. | 5,044 | |
| | | 30,344 |
| *Bekwai.* | | |
| West of railway .. .. .. | 5,000 | |
| East of railway .. .. .. | 7,290 | |
| | | 12,290 |
| *Dunkwa.* | | |
| Wiawso road .. .. .. | 3,200 | |
| Round Station .. .. .. | 4,033 | |
| | | 7,233 |
| Total .. .. | | 93,974 |

These figures merely serve as bases for careful future estimates and are obviously open to criticism. Careful surveys of the areas are urgently required. The areas at Kintampo, in the Pamu-Sunyani-Goaso triangle, and round the Dunkwa-Wiawso road are regarded popularly as centres of great potential importance and capable of extensive agricultural development.

## PRODUCTION-CENTRES OF LORRY-BORNE CACAO.

Minor centres.

The places of origin of the exports from Half Assini (581 tons), Axim (52 tons), and Ada (610 tons) are not known. For the map, they are assumed to have come from Siwum, Axim and Koforidua respectively.

Togoland production.

The production of cacao in Togoland is not known. Three centres exist, at Hohoe, Kpeve-Ho, and Peki respectively, but the extent of the industries at these centres is not known. For the map, assumed figures are used as follows :—Hohoe 2,800 tons, Ho 800 tons, and Peki-Kpeve 4,400 tons, a total of 8,000 tons. Of this amount, 4,842 tons go to Palime, chiefly from Hohoe, and the balance to Accra.

Centres supplying Cape Coast

The exports from Cape Coast (5,533 tons) probably have two sources, a major one in the areas tapped by the road to Twifu, recently extended to Brofo Yedru in Ashanti, and a minor one tapped by the road to Hemang. A provisional estimate of 1,100 tons from the latter source and 4,433 tons from the former has been used for compiling the map.

Centres supplying Saltpond.

The Saltpond exports (13,812 tons) originate from areas tapped by the road to Oda, and from those lying along the road to Winneba. Provisional estimates of 5,000 tons and 8,812 tons have been apportioned to these two production centres.

Centres supplying Winneba.

Cacao exported from Winneba (20,518 tons) is drawn from three sources, the Swedru-Nsawam road, the areas tapped by the road to Oda and Ofuasi, and the road to Saltpond. Provisional estimates of 7,500 tons, 12,000 tons and 1,018 tons respectively have been apportioned to these areas.

Centres supplying Accra.

An unknown amount of cacao, probably fairly considerable in volume, comes by lorry to Accra from points along the Accra-Kumasi road, some coming from as far as Kumasi itself. It has not been found possible to estimate this amount, nor to ascertain with certainty the centres from which it comes. It has therefore not been shown as a separate item on the map. The lorry-borne exports of Accra have been apportioned as follows :—

| | *Tons.* |
|---|---|
| Togoland Surplus after Palime Exports .. .. .. .. | 3,158 |
| Koforidua-Mampong-Aburi .. .. | 3,500 |
| Suhum to Nsawam .. .. .. | 6,500 |
| Winneba road to Nsawam .. .. | 3,500 |
| Kade-Asamankese-Nsawam road .. | 15,648 |
| Total .. .. | 32,306 |

The remainder of the exports from Accra (66,472 tons) were rail-borne, and are dealt with in the paragraph dealing with distribution to ports.

## THE NECESSITY FOR AGRICULTURAL SURVEYS.

Undeveloped S.W. areas.

A striking feature of the industry disclosed by the map is the undeveloped state of the South-western areas of the country. An arc drawn from Cape Coast through Hemang, Dunkwa and Wiawso to the French boundary encloses an area in the Central and Western Provinces, which cannot be much less than 10,000 square miles in area, almost entirely undeveloped. The area has the best and best distributed rainfall in the country (Hemang 67.06, Dunkwa 60.42, Wiawso 55.20, Tarkwa 68.86, Siwum 59.44 inches) and it is tapped by the Western Province railway, the Central Province railway and the Prestea Branch. This area should be subjected to an exhaustive agricultural survey, in order to ascertain whether any factors exist which operate against its early development.

Western Ashanti.

A careful survey of the Goaso-Sunyani-Pamu triangle is necessary. The area is popularly regarded as one of great potential value, although the rainfall (Goaso 48.05, Sunyani 54.28 inches) is below that of the great cacao-growing areas of the country.

Outlines of survey work.

The purpose of an agricultural survey of this kind should be to obtain reliable information as to the possibility of developing the area. The nature and physiography of the area, and its climatic factors, are the first points to be learnt. Number and distribution of population, and its availability for new agricultural enterprises are the next group of factors to be considered. Next should come careful consideration

of the crop or crops which offer agricultural and commercial possibilities of development in the area. Finally, the question of communications should be considered. Defects of any existing system of roads or railways should be dealt with, and the position and nature of new communications which are proposed, together with reasons for the proposals.

Agricultural census, 1930

In addition to surveys of areas of potential or rumoured importance, a census of existing areas of production is necessary. These should proceed on the same general lines as the surveys, population, physiography, communications and climatology being dealt with in the preliminary stages of any census. In the case of the cacao industry, obvious centres for census-work are the areas feeding Kumasi, Koforidua, Mangoase, Nsawam, Bekwai, Cape Coast, Saltpond and Winneba. The smaller railway-stations present little difficulty. There seems no reason why the first census should not be voluntary, but eventually the whole work should be regularly recurrent and operated under an Agricultural Census Ordinance. The preliminary voluntary census should begin now, so that correct information and reliable estimates may be available for the World Agricultural Census planned for 1930.

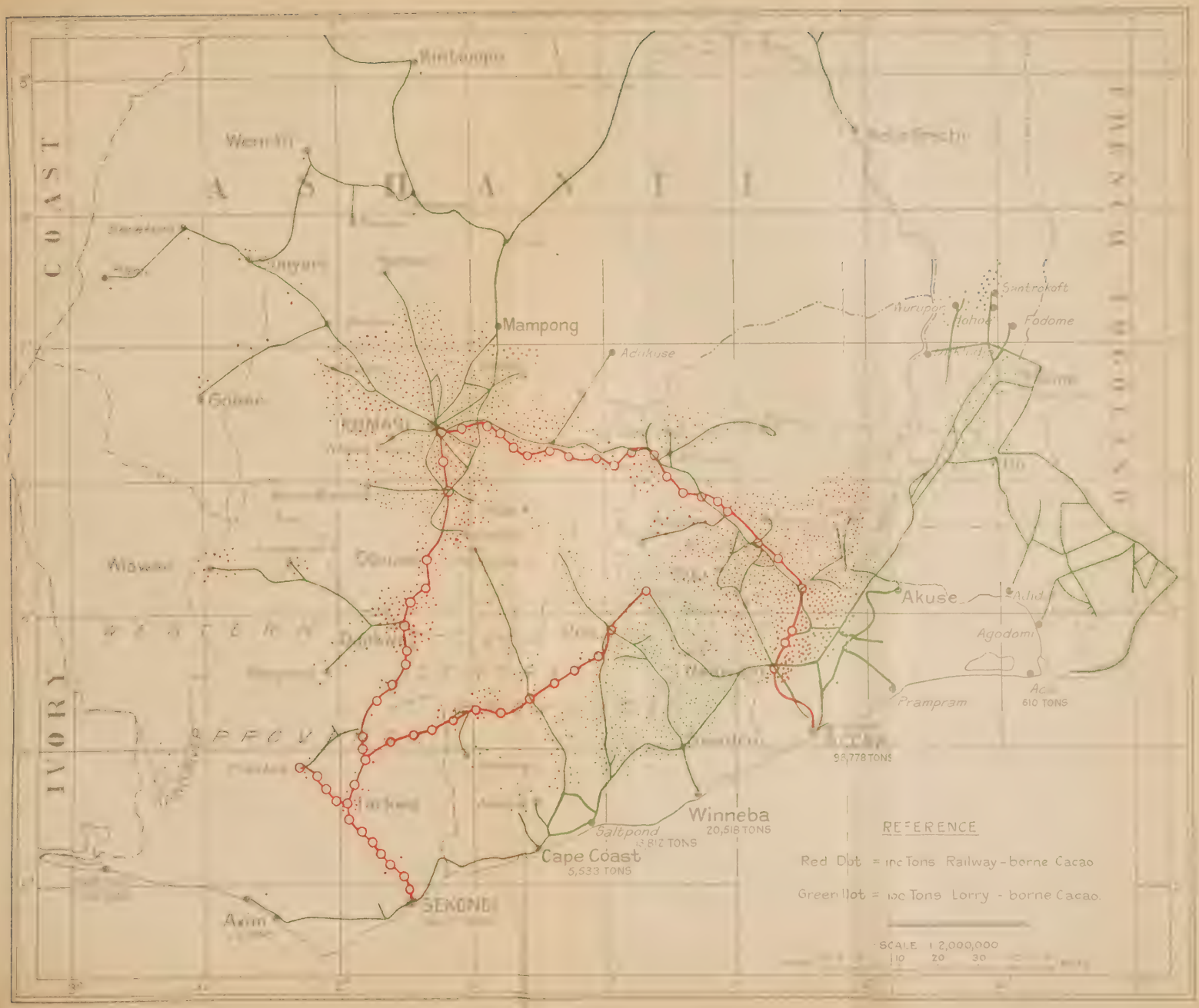
## Appendix.

SUMMARY, SHEWING FIGURES UPON WHICH THE MAP IS BASED.

| Place of Export. | Total Tons Cacao Exported 1927. | Production–Centres from which cacao came. | Tons Cacao from each Production Centre. | | | Dots placed on Map. | |
|---|---|---|---|---|---|---|---|
| | | | Rail. | Road. | River. | Red. | Green. |
| Half Assini | 581 | Tano River .. | — | — | 581 | — | 6 |
| Axim .. | 52 | Near Axim .. | — | 52 | — | — | 1 |
| Sekondi .. | 66,117 | Wiawso Road | 3,200 | — | — | 32 | — |
| | | Dunkwa Environs .. | 4,033 | — | — | 40 | — |
| | | Other W.P. Stations .. .. | 2,308 | — | — | 23 | — |
| | | C.P. Railway | 2,336 | — | — | 23 | — |
| | | Bekwai .. | 12,290 | — | — | 123 | — |
| | | Kumasi .. | 30,344 | — | — | 303 | — |
| | | Other Ashanti Stations .. | 11,606 | — | — | — | — |
| Cape Coast | 5,533 | Hemang Road | — | 1,100 | — | — | 11 |
| | | Brofo Yedru Road .. | — | 4,433 | — | — | 44 |
| Saltpond | 13,812 | Oda Road .. | — | 5,000 | — | — | 50 |
| | | Winneba Road | — | 8,812 | — | — | 88 |
| Winneba | 20,518 | Nsawam Road | — | 7,500 | — | — | 75 |
| | | Ofuasi Road .. | — | 12,000 | — | — | 120 |
| | | Saltpond Road | — | 1,018 | — | — | 10 |
| Accra .. | 98,778 | Accra-Kumasi Road .. | (not estimated separately). | | | | |
| | | Togoland .. | — | 3,158 | — | — | 32 |
| | | Mampong Road (Koforidua) | — | 3,500 | — | — | 35 |
| | | Suhum Road (Nsawam) .. | — | 6,500 | — | — | 65 |
| | | Winneba Road (Nsawam) .. | — | 3,500 | — | — | 35 |
| | | Asamankese Road (Nsawam) .. | — | 15,648 | — | — | 157 |
| | | Ashanti Stations .. | 6,317 | — | — | 63 | — |
| | | Nsawam Station East .. | 6,000 | — | — | 60 | — |
| | | Nsawam Station West .. | 12,451 | — | — | 125 | — |
| | | Mangoase Station East .. | 4,000 | — | — | 40 | — |
| | | Mangoase Station West .. | 4,223 | — | — | 42 | — |
| | | Koforidua Station Bisa .. | 15,000 | — | — | 150 | — |
| | | Koforidua Station Environs | 2,433 | — | — | 24 | — |
| | | Other E.P. Stations .. | 16,048 | — | — | 161 | — |
| Ada .. | 610 | Koforidua area | — | — | 610 | — | 6 |
| Palime .. | 4,842 | Togoland .. | — | 4,842 | — | — | 48 |
| Totals .. | 210,843 | | 132,589 | 77,063 | 1,191 | 1,325 | 783 |
| | | | 210,843 | | | 2,108 | |

# DEPARTMENT OF AGRICULTURE.

CACAO PRODUCTION AND EXPORT.



## PAPER No. VII.

# DEFECTIVE CACAO.

By R. H. BUNTING.

The cacao markets of Europe and America recognise, and regulate the sale of cacao beans according to the percentage of certain defects in the produce. So far as can be ascertained no food definitions of these defective beans exist. In some cases they are attributed to wrong causes, and it is possible that purchases may be made on certain points of appearance which do not necessarily indicate the quality of the beans examined.

In an attempt to eliminate defects it is obviously necessary to ascertain their causes, and whether the causes can be avoided either by cultural measures in the field, or by methods of preparation of the produce.

This paper is an attempt to standardise defective beans in the hope that it may help to correlate defects with their causes. In this respect it should be mentioned that, with the exception of figures 7 and 8, Plate IV, and figures 3, 4, 5 and 8 Plate V, the results illustrated on the accompanying plates have been obtained by deliberate exposure to such conditions as were considered to be causative of the effect shown. All cases mentioned and illustrated refer to the common variety grown in this country—Amelonado. Trials of cause and effect have not been so exhaustive as could be wished, but sufficient knowledge is considered to have been accumulated to justify publication.

Apart from damage caused by insect attack the primary division of the causes of defective beans differentiates between those of faulty preparation and those of natural conditions. In the majority of cases the former class are usually preventable by the correction of operative measures, or actually by the exclusion of fresh beans which, it is known, could never be converted into good produce. It is possible that better cultivation might produce a smaller percentage of what may be called physiological defectives, e.g, under-developed beans: it is equally possible that certain defects in preparation, e.g. too prolonged a drying period, could not be overcome on an economical basis. The economics of such control problems are not considered to lie within the province of this paper, but, in passing, it does appear to the writer as an irrefutable fact that were there no demand made by local purchasers for cacao of an inferior quality the percentage of defective beans would fall to an economic minimum.

## METHODS OF PREPARATION.

The usual method employed by local producers to prepare cacao beans for market consists of heaping the beans, together with the mucilaginous contents of the pod, on banana or similar leaves placed on the ground, and of covering the resulting mass with a further supply of leaves. Modifications of this method are those in which a pit is dug in the ground, or a basket used above ground, to contain the dehusked crop. The aim of each method being to produce the result known to purchasers as fermented cacao.

The period of time before the fermenting mass is disturbed varies in differing circumstances. Six to seven days is commonly regarded as a desirable period, but cases have been known when a favourable market has induced the owner to break up his heap within three days, whilst, on the other hand, farmers are known who open up their fermenting heap in order to mix the contents during the fermenting period—a highly desirable operation too often neglected.

The method used, and advocated by, the Department of Agriculture is arranged by placing three boxes of similar size in stepped tiers so that the beans after 48 hours in the top box are shovelled through a sliding door into the middle box where they remain for a further 48 hours, after which they are similarly removed to the lowest box from which they are removed at the end of the sixth day to be sun-dried.

Trays of matting built about 2½ feet from the ground, concrete floors, tarpaulins, or the bare ground are used for the purpose of exposing the fermented beans to sun heat. The period required to dry the beans necessarily depends upon weather conditions, and is roughly gauged by touch. Precautions are taken to avoid dampening by rain or dew by covering the beans during moist conditions, but imperfect drying frequently occurs owing to competition for such produce by local purchasers.

## NORMAL FERMENTATION.

The complex processes which take place in cacao beans, and which for want of a better term are collected under the title "fermentation" are not completely known. The visible results are a change in colour and texture of nibs and shell. Colour changes can also be produced by laboratory methods at a suitable temperature without the agency of external organisms.

A freshly cut Amelonado bean presents the purple coloured section shown in Plate IV, figure 1. This colour changes immediately upon exposure to air to a darker, much bluer violet, whilst the radicle ("germ") assumes a rusty brown colour. After six days

# Plate IV.

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in fermenting boxes, the beans, when cut, show the reddish purple indicated by figure 2, and contain in the interstices formed by the folds of their cotyledons a chocolate brown liquid. When dry a fermented bean presents internally the rich brown colour known to all buyers as " well fermented."

## SLATEY BEANS.

If an Amelonado bean be washed free of its mucilaginous matrix and dried at shade temperature its colour changes from the fresh purple of figure 1 to the dull flat slate colour shown by figure 5 Slatiness, so far as it relates to colour, may be regarded as the natural condition of a dried cacao bean The objectionable colour may readily be converted to a purple by boiling in water, or by the application of a warm acid solution, and, as in the case of a fresh bean, the application of an alkaline agent converts the purple colour to slate. If, however, beans are allowed to dry with no precautions being taken to maintain a low temperature, to prevent the mucilage becoming acid or the internal enzymes to function, the result in colour may be purple rather than slate, even though no active measures have been taken to promote fermentation. So that it is more accurate to state that a fermented bean cannot be slatey, than that slatiness is caused by insufficient fermentation.

## INSUFFICIENT FERMENTATION.

In the methods of preparation adopted by local producers, when the fermenting mass is allowed to remain undisturbed until removal for drying, the resulting produce consists of beans varying in colour from pure slate to chocolate brown. Intermediate between these two colours are combinations of a central purple area with a brown border, and grades of purple. Figure 3 is representative of the latter, portraying a bean which was dried after 88 hours in fermenting boxes.

The cause of the assortment of colours which result from an unturned fermenting heap is the fact that fermentation throughout the heap is irregular in intensity ; whilst well prepared beans may be taken from the centre, at the bottom and around the ground circumference of the heap slatey beans predominate, and intermediate stages occur elsewhere.

It is worthy of note that an indiscriminate sample of mixed beans taken from a native drying mat and stored for nine months in a closed vessel attained the desirable chocolate brown colour shown in figure 4, a colour which was uniform throughout the sample. Other trials of an improvement in colour by the storage of imperfectly fermented beans have proved successful over shorter periods than nine months.

Cases have been known in which germination has taken place during the first day's exposure on the drying mat—a clear indication that sufficient heat was not generated during the process of fermentation. Figures 7 and 8 show beans which had thus germinated, that marked 7 having been drawn after one day's exposure to the sun, and 8 another bean of the same batch completely dry. The latter illustration also indicates that slatiness normally occurs at low temperatures.

In this connection, and before leaving the subject of colour changes in the cotyledons, it may be of interest to record that the application of heat (60°C. for 3 to 6 days) to fresh Amelonado beans gave uniform results which would have satisfied the most fastidious examiner as to a perfect fermentation appearance. That temperature plays a part in the colour changes of the nibs is also shown by the fact that in a test for anaerobic activity in fresh Amelonado beans, those kept at 40°C. in an atmosphere of hydrogen were purple or brown, whilst those in hydrogen at laboratory temperature were all slatey-purple. Whether the fact of fermentation can be ascertained by the external appearance of a dried bean seems to be open to considerable doubt since it is at least possible that external colour may be influenced by variable drying conditions.

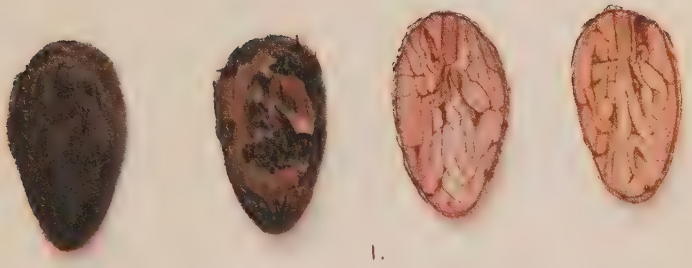
## CHANGES IN TEXTURE.

Beans when taken from the pod consist of the closely packed, fleshy and complicated folds of the two cotyledons which when dry are known as " nibs." The cotyledons are connected at their bases to the embryonic root—the " germ "—and the whole embryo is enclosed by the seed-coat or " shell." During the process of fermentation the bean becomes swollen by a wine-coloured fluid which ultimately changes to a brown colour (see fig. 2) and which distends the interstices contained in the seed-coat. So then, when dry, the bean presents the loose shell and desirable break of commerce. The amount of distension caused by the presence of this liquid may be judged by the evident pressure it demonstrates when a fermenting bean is pricked and the fluid exuded.

Incomplete fermentation resulted in the case shown as fig. 3 (and in similar cases) in a partially cheesey bean with a tightly adherent skin. Microscopic examination of the structure of a cheesey bean compared with that of a well fermented bean with a good break showed no significant difference, and until more is known of cheesiness it may be assumed that that condition is prevented by a sufficient period of fermentation and by suitable drying conditions.

It is probable that changes in the texture of the seed coat occur during fermentation since observations have shown that the cotyledons of fermented beans are more readily accessible to moulds

# Plate V.



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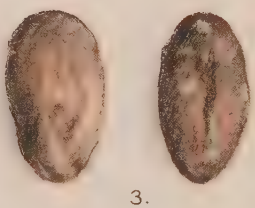

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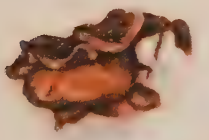

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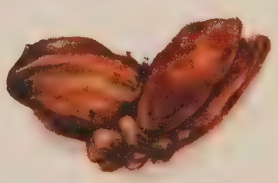

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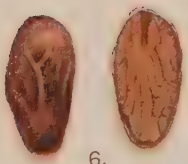

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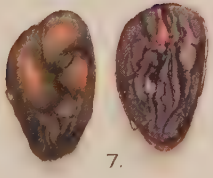

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than are those of unfermented beans. On the other hand no structural change has been observed in the seed coat by microscopic means and the facilities for infection can merely be stated to be greater in beans subjected to fermentation than in those dried immediately after dehusking.

Trials of the effect of different degrees of temperature and length of time taken in drying, on plumpness, loose shell and other textural features have not yet been undertaken. In cases where drying has been done artificially moulding has not been known to occur under conditions that permitted the development of moulds in sun-dried beans.

## DEFECTS DUE TO PREPARATION OF BAD MATERIAL.

Defective produce which could be avoided by the exclusion of unsuitable raw material from the fermenting mass, apart from extraneous matter, is the result of various causes.

### Germinated beans.

Pods collected when over-ripe may contain beans in stages of germination ranging from those in which the husk is perforated by a circular hole immediately opposite the germ to such as is shown in figure 6. As in the latter case, germinated beans are sometimes contained in diseased pods, the maturity of which cannot be estimated on account of the blackened condition of the pod.

### Diseased beans.

When pods are so badly infected by disease that the causative fungus is found within the seed-coat, the resulting colour of the cotyledons immediately after fermentation is a fawn to pallid purple as is indicated in Plate V, figure 1. The beans from which figure 2 was drawn were taken from the same pod as those of figure 1 and represent the dried result. It will be noticed that they have recovered a more or less normal colour in drying. The blackened condition of the husk in these diseased beans was caused by the presence of the brown mycelium of *Botryodiplodia theobromae*—a fungus which is frequently found as a secondary organism in diseased pods. As the term " disease " implies that the host affected was living at the time of the attack of any pathogenic organism the misuse of the term for describing prepared beans affected by moulds should be avoided and its use retained for such cases as are described above.

### Underdeveloped beans.

In all normally grown pods there are found a few seeds which have never become fully developed.

Such malformed seeds assume many shapes but are always flat. Figure 4 shows some which were taken from a native drying tray after fermentation, and the sections through them, marked 4*a*, show their worthlessness to the cocoa manufacturer. Stringy portions of the placenta—" guts "—were found adhering to them, which should also be excluded from the finished produce—figure 5 shows similar beans from a different fermentation batch.

It is possible that trees bearing nothing but fully developed seed might be bred by selection, or that an improvement might be obtained by intensified cultivation, but until those conditions are realised flat beans should not be included in produce that is expected to attain normal qualifications.

The crop resulting from uncongenial climatic conditions, such as may occur during the growing season preceding a mid season crop, is likely to consist more or less of under-developed but mature beans—a contingency which cannot be avoided by ordinary cultural measures.

### Immature beans.

Under-developed beans are frequently described as immature, an unfortunate term which implies that the pods are gathered before they are completely ripe. Such a custom is traditionally opposed to native practice with other crops and is unlikely to be of common occurrence.

Except possibly in the matter of size, the writer has found it difficult to distinguish between beans prepared from decidedly immature pods and those of full maturity. The contents of immature pods have been prepared for such a comparison ; figure 6 shows a typical bean from one such pod after having been fermented and dried; figure 7 is of a similarly derived bean dried with no previous treatment.

## DEFECTS OWING TO WEATHER CONDITIONS.

### Prolonged Drying.

Prolonged and intermittent drying caused by wet weather resulted in the external appearance of the beans shown in figure 3. The earthy appearance of these beans was suspected of being caused by the presence of *Actinomyces*, but microscopic examination showed only dried up colonies of yeasts. There was some indication that the internal appearance of the beans had been improved by the intermittent continuation of fermentation which took place during those periods when the beans were gathered into heaps for protection against the weather.

# Plate VI & VII.

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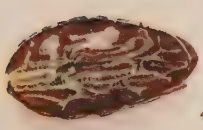
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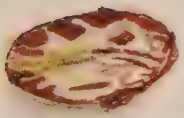
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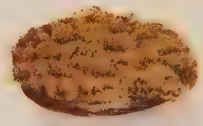
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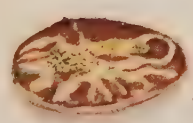
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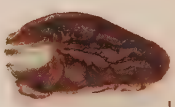
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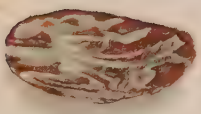
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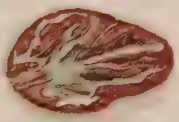
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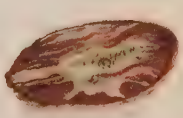
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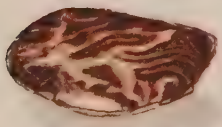
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**White Spot.**

The occurrence of white spots on all parts of the cotyledons of dried beans caused some consternation amongst buyers a few years ago, and was suspected by them of being a new "disease." Manufacturers of cocoa reported both adversely and favourably on consignments containing a high proportion of such beans as are shown in figure 8.

Attempts to obtain an organism in these white spots by the usual laboratory methods gave negative results, and the cause was attributed to rapid evaporation during fermentation—a condition due to a period of harmattan weather—the result of excessive evaporation being small deposits of cacao-fat and other solids usually carried away with the "sweatings." Similar deposits were produced by laboratory methods.

**Moulded beans.**

One of the most serious defects in fermented cacao beans exported from this country is that caused by the presence of internal moulds. Certain of these moulds occur on the beans during fermentation and are capable of increasing the temperature of the mass above the normal maximum. Other moulds require a high amount of moisture for their development, whilst a minority occur on commercially dry cacao that has been stored for a sufficiently long time in a damp atmosphere. Nine distinct species of moulds are depicted on Plate VI. Other species than those illustrated occasionally occur, and frequently more species than one are developed within the same bean. It should be noted here that since the presence of a mould on the outer surface of the bean does not necessarily indicate internal moulding, external moulds are not considered in this respect to be defective.

It is sufficient to record here that investigations, up to the present, show that the presence of moulds in cacao could be almost entirely avoided were nothing but well dried produce purchased from the farmer and removed before it had an opportunity of coming into contact with a damp atmosphere or of being wetted. In this connection it may be reiterated that contact with salt water is as efficient a method of inducing the development of moulds as rain or other source of fresh water. It is equally true that every bean purchased may be considered to be infected by the spores of one or more of the moulds before leaving the producers' hand, so that too great a care cannot be taken to dry or to maintain their dry condition in an endeavour to exclude the possibility of moulds developing.

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*N.B.*—Throughout this paper, the word "cacao" is used wherever a raw part of the plant is being considered. The word "cocoa" is reserved as the name of the commercial powder manufactured from the bean.—EDITOR.

## PAPER No. VIII.

# FUNGI OCCURRING IN CACAO BEANS.

By R. H. BUNTING.

One of the most frequent defects of cacao beans exported from this country is due to the presence of one or more of a number of moulds on the embryo of the prepared beans.

The presence of any internal mould deteriorates the value of cacao intended for human consumption; cocoa* and chocolate manufacturers are unable to utilise it in appreciable quantities on account of the flavour it imparts, and the markets, influenced by the pure food campaign, are becoming more resolute in refusing to purchase parcels of cacao containing more than a limited percentage of moulded beans.

The desirability of ascertaining what organisms cause moulding was influenced not so much on account of their direct effect on the constituents of the produce as because of the factors which contribute to their development, since it is their presence rather than their function which is objectionable.

In early attempts to ascertain the minimum amount of moisture that is necessary to induce or to maintain the growth of moulds in cacao beans, it soon became apparent that for this reason alone it would be necessary to separate as accurately as possible the various organisms for individual treatment. This paper is an endeavour to elucidate, morphologically rather than physiologically the ever growing number of species involved.

Considerable difficulty has, however been experienced in delimiting the bounds of variation which occurs in shape and size of almost any given part of the organisms concerned, so that one has to rely upon general characterisation rather than upon definite characters for the determination of individuals.

One or possibly more of the undetermined species may be new to science. Descriptions and illustrations of them are given and their position in nomenclature left to special systematists.

## GENERAL CLASSIFICATION.

From the practical point of preparation, the moulds affecting cacao-beans may be divided into three sections according to the conditions in which they are found.

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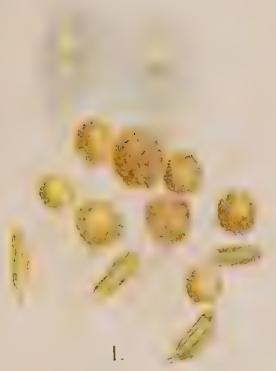
*N.B.*—The word "cocoa" means the manufactured, commercial powder. "Cacao" is used for any raw part of the plants.—Editor.

# Plate VIII.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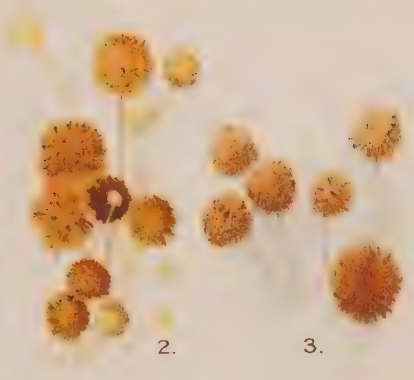
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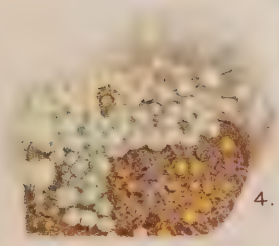
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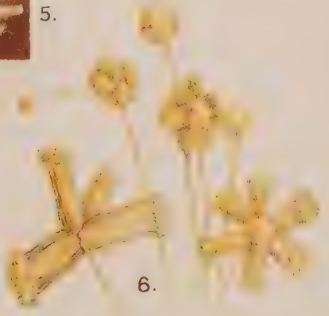
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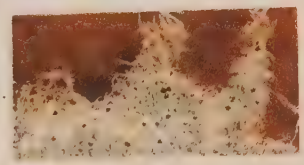
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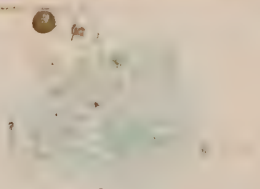
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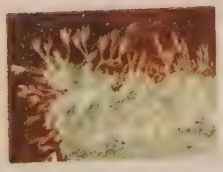
500 μ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10.

R. H. B. del.

John Bale, Sons & Danielsson, Ltd

I. Apart from numerous yeasts, the fungi which are first encountered in the preparation of cacao-beans are thermophilic and, in one case, thermogenic; they occur with some frequency in fermenting masses and may increase the temperature beyond that of an unaffected fermentation.

II. In prepared beans which have a high moisture content the most prevalent moulds are those of the larger *Aspergillus* species having secondary sterigmata.

III. The third section occur on what is usually considered as dry cacao and which has been stored for some time, and consists of a member of the *Aspergillus glaucus* group with an ascigerous stage, and a species of *Penicillium*.

As an example of the complexity of problems relating to the moulding of cacao beans, it may be mentioned here that in several instances, where indeterminate mycelia were found infesting embryos, one half of a bean incubated under aseptic conditions at 40°C. resulted in the development of one or other of the thermophilic moulds, whereas the complementary portion of the bean grown at laboratory temperature developed one or more of the other moulds.

The commonest, and therefore most important, of the cacao moulds are confined so far as observations have gone, to the orders Mucoraceae and Aspergilleae. Other fungi occasionally occur in cacao-beans, such as *Botryodiplodia theobromae* on beans inadequately prepared from diseased pods, *Cladosporium* sp. on beans stored for a long time. *Monilia sitophila* is of still more rare occurrence, whilst many searches for species of *Actinomyces* have, with one known exception, given negative results, so that Ciferri's observations regarding obnoxious fungi on cacao-beans in Dominica (*a*) would seem to be inapplicable to the produce of this country.

The genus *Aspergillus* provides the chief offenders in local cacao-beans, its species include members of the following group :—

*A. fumigatus*, *flavus* (two forms), *glaucus*, *ochraceus*, *tamari* and *niger* (three forms). Of the Mucoraceae, a cymose species of Mucor, two species of *Absidia* and one of *Circinella* have been found.

## I. THERMOPHILIC MOULDS.

### Ia. Aspergillus fumigatus Fresenius group.

(Plates VII, figs. 4 and 5. VIII, fig. 5, IX, fig. 4.)

Frequently found in fermenting heaps in native farms, particularly when such masses of beans are not disturbed. It occurs as a fairly compact glaucous mould approximating the colour of figure 5 on Plate VII, adherent to the surface of the

(*a*) Ciferri : Studien über Kakao I. Centralblatt, für Bakt. Ab. 2, LXXI, 1–7. pp. 80–93, 1927.

beans, and occupying the warmer areas of the heaps. It is absent from the centre of the heap probably on account of its development being inhibited by the high saturation of $CO_2$ in that region since the temperature generated there never reaches the thermal death-point.

Its thermogenic activity is indicated by the fact that, in one mass where it developed, the temperature rose to 54°C., i.e., 8 degrees above the usual temperature attained in box-fermentations. Spores suspended in a liquid nutrient medium, and subjected to a temperature of 67°C. for ten minutes, survived to form abundant sporophores, and it is possible that further tests at higher temperatures may also show survival.

By colorimetric methods the cultivation of *A. fumigatus*, derived from local cacao-beans on media of the approximate pH indices 4.5, 5.6 and 7.2 produced in three days reactions which gave 6.5, 7.0 and 7.5 respectively.

The question of pathogenicity to animals of the local strain of this species arose as a result of numerous references in literature to various mycoses in man and fatal diseases in birds which are accredited to *A. fumigatus* Fres. An attempt to test whether the cacao-bean *fumigatus* was pathogenic to animals by infecting the abrased skins of a monkey and a dog gave negative results, but since animal diseases caused by members of this group are usually pulmonary, or such as affect the mucous membranes, the trial should not be regarded as conclusive.

Thom and Church in their monograph of the Aspergilli differentiate, in their discussion of the group of which *A. fumigatus* Fres. is the type, between perithecial forms and those with similar conidial forms but no perithecia [(*b*) pp. 219]. Neither in cacao-beans nor on artificial media has the Gold Coast strain been found to produce perithecia. It falls naturally within the general characterisation of the conidial stage of the group as given by these authors. Morphologically therefore, it may safely be regarded as *A. fumigatus* Fres.

Conidial heads of this mould taken from a cacao-bean are illustrated at a magnification of approximately 32 times in fig. 5 of Plate VIII, and its general appearance within a cacao-bean is shown on Plate VII by fig. 4 ; figure 5 of the same Plate shows the growth which developed at a temperature of 40°C. Colonies both on the testae and embryos of cacao-beans, and on Dox's agar medium* are velvety, rarely if ever approaching

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(*b*) Thom and Church : The Aspergilli, 1926.

* Dox Agar, as used for the moulds mentioned in this bulletin :—

| | | | |
|---|---|---|---|
| Pot : nitrate | 2.0 | Cane-sugar | 15.0 |
| Mag. sulphate | 0.5 | Ferric chloride | 1 drop. |
| | | Agar. .. | 15.0 |
| Pot. phosphate | 1.0 | Water up to | 1,000.0 |

a floccose condition, in colour they vary according to age from glaucous green (Ridgway XXXIII, 39″, d) in young cultures and in cacao-beans to olive and later to natal brown (R. XL, 13‴, m).

The sporophores (Plate IX. fig. 4) are small and densely crowded, they are smooth and unseptate, hyaline at first becoming more or less fuliginous in old cultures, 130 to 400μ in length widening gradually from 3 to 5μ at the base to 6 to 7μ below the vesicle, which is elliptical, sometimes with a depressed apex, and up to 24μ in diameter. The sterigmata are in a single series crowded around the upper part of the vesicle and parallel to the axis of the conidiophore, they measure 6 to 10 by 2.5μ. Conidia are borne usually in cylindrical heads up to 150μ long by about 30μ in diameter, but in all cultures some more or less loose, globular heads may be found; the spores are spherical, 2.5 to 3μ in diameter, tending towards an oval, less regular and slightly larger form in old cultures up to 4 x 2.5μ; in a mass they are green in colour.

The smaller and smooth spores, non-septate sporophores and cylindrical heads distinguish this species from *A. glaucus*—the only other form with which it is likely to be confused on cacao-beans. The facts that the latter fungus produces a perithecial stage, cannot be regarded as thermophilic, and utilises a drier substratum, are also of diagnostic assistance.

The importance of *A. fumigatus* in problems relating to the moulding of cacao-beans lies less in its persistence as an active mould in the dry produce, than in the fact that it occurs in fermenting masses, and may be the means by which other and more persistent moulds enter through the protecting seed-coat. Experimental work on this point has shown that the fungus can penetrate the testa of a fermented bean, as was to be expected from the fact that it has been recorded (Thom and Church; pp. 67 and 68) that certain members of this group have been shown to be capable of destroying cellulose, and to be active in the destruction of the pentosans of maize-forage and rye-straw (*c*).

### Ib. Mucor sp.

(Plates VII, figs. 14 and 15, VIII. fig. 10, XI).

The second thermophile found in fermenting heaps belongs to the cymose group of the Mucors, and is probably a new species. It develops from a white floccose vegetative mycelium to a somewhat more compact, sporangial mycelium of a deep olive grey colour (R. LI. 23⁗), which extends to a depth of three inches from the surface of the heap. It is frequently associated with *Aspergillus fumigatus*, and is probably more common in native fermenting heaps than the latter.

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(*c*) Schmidt, Peterson and Fred: Soil Science XV. pp. 479–488; 1923.

This Mucor has also been cultivated from cacao-beans prepared for export, and has been found on copra stored locally. Early stages of its development in the interstices between the folds of the cotyledons of a cacao-bean are of a light grey colour, which changes to a light olive buff, such as are shown in figures 14 and 15 of Plate VII.

A suspension of spores in a liquid medium survived an exposure to a temperature of 67°C. for ten minutes. The association of this fungus with *Aspergillus fumigatus*, and the fact of its thermophilic tendency, permit the suspicion that it may be parasitic on warm blooded animals as is *Absidia lichtheimi* (*Mucor corymbifer* Cohn.) a species for which it was at first mistaken.

Prof. S. F. Ashby (in lit.) stated that he was unable to find a place for this *Mucor* in any of the recognised species of the cymo-Mucors where it obviously belongs, that its action on starch is weak, and that he could detect no alcohol in cultures on malt extract*.

The fungus is shown (x 32) in fig. 10 of Plate VIII as a group of sporangia from a young colony; details of its structure reproduced from camera lucida drawings are given on Plate XI.

The mycelium is hyaline, but becomes dark brown in old colonies, it shows a decided tendency toward a torulose condition with occasional intercalary chlamydospores which are from 11 to 30μ in diameter. Sporangiophores are hyaline, soon becoming dark brown, they arise from a narrow base which may be not more than 3μ in width; on some media sporangiophores and pedicels develop a coarse obese appearance than can only be regarded as abnormal. The sporangia are borne in simple or compound cymes, an arrangement which is sometimes confused by the development of a number of short pedicels arising from the main axis near the terminal sporangium. The pedicels usually increase in width from a narrow base up to 15μ at the insertion of the sporangium, they become septate below the terminal sporangia, and are fuliginous above, and brown below the septum.

The sporangia are spherical, erect, minutely echinulated with crystals, and diffluent; they vary in size up to 80μ in diameter, the smaller ones sometimes being almost apophysate.

*At the time of going to press Professor Ashby (in lit.) states that Professor Lendner confirms the suspicion that this is a new species, and will describe it.

# Plate IX

The columellæ are faintly fuliginous, either smooth or rough, subspherical to oval, up to 50μ in diameter. The spores are also somewhat fuliginous, subspherical to oval, frequently irregular in shape, smooth, differing greatly in size usually 3-5μ in diameter, but up to 8.5μ.

## II. HYGROPHILIC MOULDS.

The four groups of *Aspergillus* which are represented in cacao-beans with an abnormally high moisture content are differentiated chiefly by colour into *Aspergillus niger, tamari, flavus* and *ochraceus*. Their presence may be regarded as indicating either that the produce has not been dried sufficiently during preparation, or that it has come into contact with moisture subsequently. For this reason they are not considered of such economic importance as are those which infect drier beans.

### Ia. Aspergillus niger Van Tieg. group.

(Plates VII, fig. 10, VIII, fig. 7, X, figs. 2, 3, and 4).

There are at least three morphologically distinct forms of *A. niger* found in connection with cacao-beans in this country. They are shown grouped together in fig. 7 of Plate VIII at which magnification they cannot be readily distinguished from one another, since each may present a warm deep brown to almost black, soft, mealy appearance when growth is luxuriant. The conidial heads, of which the mass is composed, vary in diameter at maturity from 120μ to more than a millimetre; at younger stages they are usually hyaline and may pass gradually through darkening olivaceous tones, or may with few perceptible changes of colour reach the dark brown colour of maturity; they are always spherical at first, but may split up into columnar segments, remain compact, or become shaggy. The vesicles are always spherical, differing very considerably in size, usually thick walled; and either smooth or punctate at the bases of the sterigmata which arise from their entire surface. They, like the stalks of the sporophores, are usually coloured.

The three local forms are detailed on Plate X under the figures 3, 4 and 2, which for convenience of description may be cited as A, B and C respectively.

*Form A.* (fig. 3) appears to conform to A. *luteo-niger* (Lutz.) which was collected on fermenting cacao beans in San Thome (Thom and Church; p. 166). In young growths conidia are borne directly on the primary sterigmata which are about 10μ in length; more typically one to three secondary sterigmata are borne on those of the primary series which may then attain a length of 30 or even 40μ. The thick walled, dark-

brown, tuberculate, globose spores of 3.5–5μ diameter are, in conjunction with the comparatively short primary sterigmata, the chief characteristics of this form. It should also be noted that usually the stalk of the conidiophore decreases in width toward its junction with the vesicle.

*Form B.* (fig. 4) differs from A. chiefly in the size of the spores which are from 7 to 12μ in diameter. They are globose, fuscous to dark-brown, occasionally almost smooth, spinous, tuberculate or with numerous conical protuberances that are up to 3.5μ in length. The primary sterigmata are usually truncate and of rather more generous proportions than those of form A., they bear from one to three secondary sterigmata. The sporophore stalk shows no tendency toward a narrow neck, but is frequently roughened, apparently by pits.

*Form C.* (fig. 2) is distinguished from either of the other forms by its elongated primary sterigmata bearing up to twelve or possibly more, secondary sterigmata. Those of the primary series are clavate, arising from a narrow base sometimes not more than 1μ in width, they vary in length from 40 to 110μ, and are occasionally septate. The conidia are spherical, 4–5μ in diameter and are comparable with those of form A. except that a larger proportion of light coloured, smooth, or almost smooth, spores usually occur. The sporophores are usually smooth, hyaline or coloured, up to 24μ in width, and split readily under pressure into strands, they arise from a slender base frequently involved in a tangle of narrow, thin walled hyphae that make it difficult to discern the foot-cell.

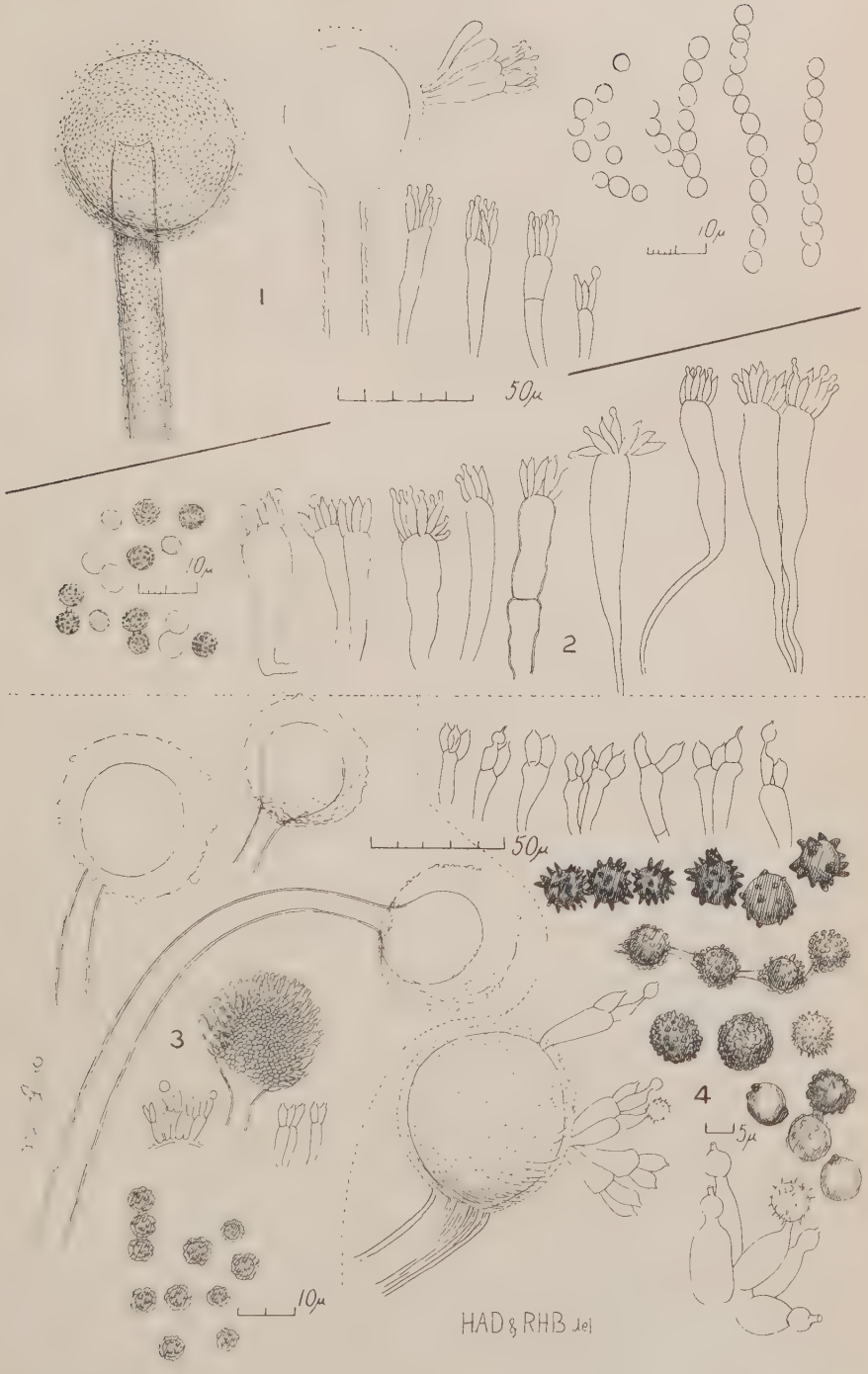
### IIb. Aspergillus tamari Kita group.

Plates VII, fiig. 6, VIII fig 3, IX, fig. 6).

In cacao beans this mould presents the white to medal-bronze (R. IV. 19′, m) colour shown by fig. 6 of Plate VII, and darkens to mummy-brown (R. XV. 17′.m) in old cultures ; grown on Arbutin agar it became a deep beetroot colour. Its enzymatic activity has been found to be positive in the case of tests for amylase, emulsin, lipase, protease, erepsin, trypsin and amidase, and it is reported as apparently not producing acid.

*A. tamari* is not found with great frequency in cacao beans ; it occurs as conspicuous masses of small and compact, or much larger, shaggy, globose spore heads, that may usually be distinguished from a similarly coloured strain of *A. flavus* by their greater length of stalk. The sporophores are usually long, hyaline, sometimes pitted, and arise from a slender base widening gradually towards the vesicle. The vesicle is globose and thin walled bearing sterigmata on the whole of its surface ;

# Plate X.



in some cases simple sterigmata bearing chains of conidia occur around the base of the vesicle. Commonly there are two series of sterigmata, the primary ones being 10–20 x 6–10μ in size, compactly arranged and bearing rarely more than two secondary sterigmata which may be of equal or greater length. The conidia are almost pyriform to obovate, yellow brown in colour, tuberculate when fully formed, 7–10 x 6–7μ. Its characteristic features other than colour are the usually equal length of secondary and primary sterigmata and large spores.

### IIc. Aspergillus flavus group.

(Plates VII, figs. 7, 8 and 9, VIII figs. 1 and 2, IX, fig. 5).

As in the case of local copra moulds, there appear to be two forms of the *flavus* group occurring on and in cacao-beans. The commoner is represented by figure 8 of Plate VII and the other by fig. 9 of that Plate. Figures 1 and 2 of Plate VIII indicate the distinctive colours of the two forms at the magnification given.

In culture the colonies are widespread and smooth, zonate when grown on maize meal agar ; those of the lighter coloured form varying between parrot green (R. VI. 31. k) to warbler green (R. IV. 23. k) and darkening with age to bistre (R. XXIX. 15″. m). The darker coloured form is medal bronze (R. IV. 19. m) with a border of pyrite yellow (R. IV. 23. i) on Dox agar. The mycelium and young sporophores are hyaline, and as the fungus grows rapidly an early growth completely filling the interstices of a cacao-bean may appear white, as does the advancing periphery of a developing colony on artificial media.

There are no very individualistic anatomical characters differentiating this group from others of the larger Aspergilli. The hyaline, minutely pitted and occasionally septate stalks of the sporophores increase gradually in width from a narrow base to their junction with the elliptic or globose, yellow-brown, punctate, vesicles. There are typically two series of sterigmata but heads with a single series of short sterigmata are common in the lighter coloured form. In this strain columnar heads of spores are not uncommon owing to the development of sterigmata being sometimes limited to the upper two-thirds or smaller proportion of the vesicle. The spherical to somewhat pyriform conidia of the two forms differ ; those of the lighter colour being smaller—3.5 to 5.5μ in diameter and either almost uncoloured or yellowish with indistinct markings, whilst those

of the darker form are from 5 to 6μ in diameter, yellow-brown in colour, with conspicuous irregular thickenings in the form of tubercles or indefinite bands. In figure 5 of plate IX the spores on the left side of the dotted line are those of the lighter coloured strain, those on the right are of the darker form.

No perithecia or sclerotia have been found, though knots of frequently septate hyphae have been found suggestive of incipient sclerotia.

The distinctive characters of the two strains have not been fully worked out but several generations on various media appear to indicate constant differences which are also found to obtain on similar forms obtained from damp copra.

The yellow-green strain constantly occurs on insufficiently dried cacao beans and is one of the first to appear, it is also occasionally found on the outside of fermenting masses of beans when the temperature is less than normal. Spores suspended in a liquid nutrient medium were found to develop after being subjected to a temperature of 50°C. for ten minutes.

The enzymatic activities of this strain are comparable with those given for *A. tamari*.

### IId. Aspergillus ochraceus Wilhelm group.

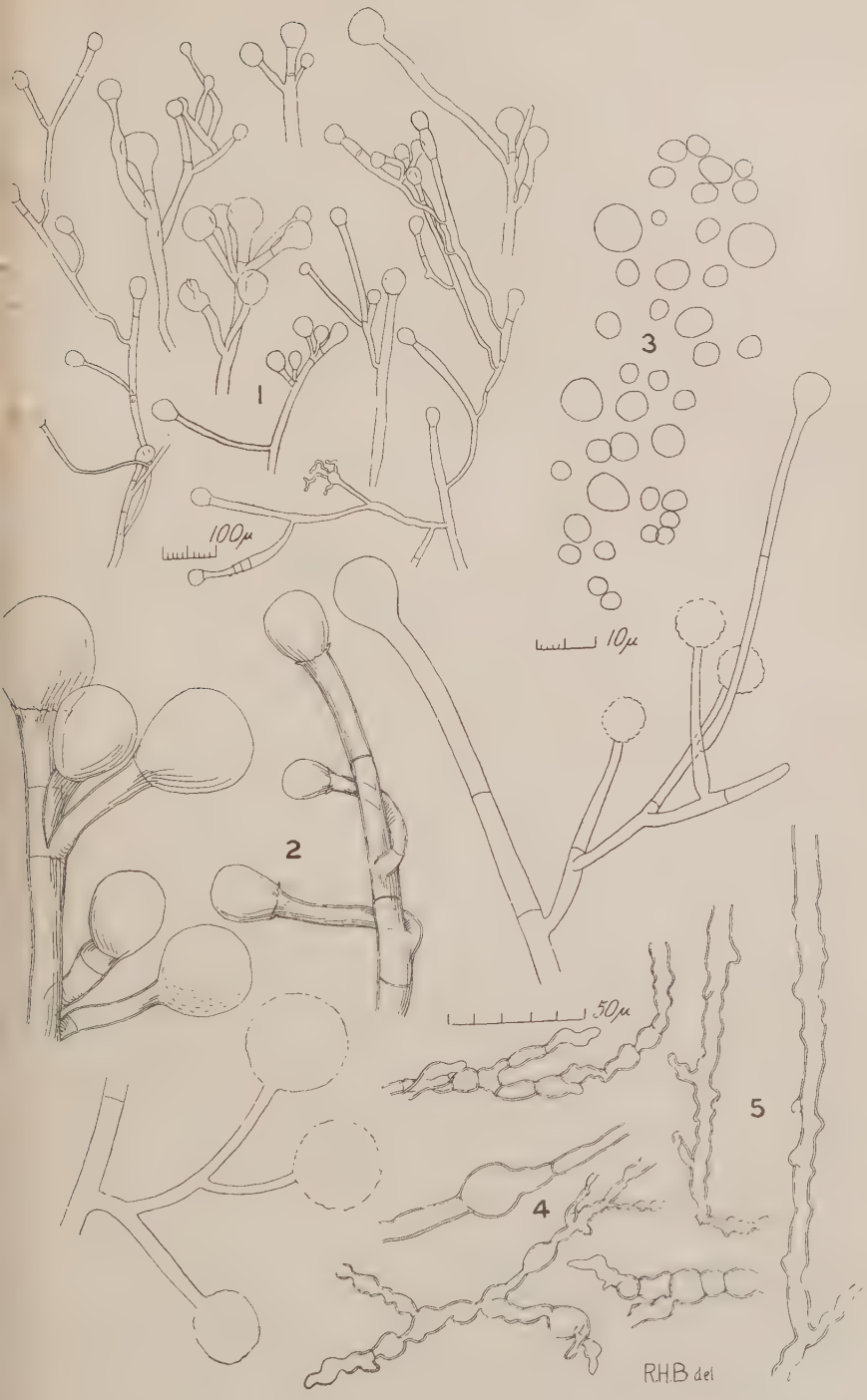
(Plates VII, fig. 11, VII, fig. 6, X, fig. 1).

This conspicuous mould is probably the least common species of the larger Aspergilli found in cacao-beans. Its presence is revealed by light buff conidial heads apparent to the naked eye, arising from a white to honey coloured mycelium which also bears numerous sclerotia of a similar colour. In old cultures the conidial heads deepen to warm-buff (R.XV.17′.d.) and the sclerotia to an ochraeous buff (R.XV.15′.b.).

The spore heads, which are at first globose, develop into cylindrical segments radiating from the vesicle, and sometimes bear secondary and smaller heads as is shown in figure 6 of Plate VIII.

*A. ochraeus* most closely resembles in structure the local strain of *A. niger* referred to as form C. on page 50. It has cylindrical, rough stalks with globose, punctate, vesicles of about 70μ diameter ; the walls of the vesicles may be up to 6μ in thickness. The primary sterigmata are sometimes septate,

# Plate XI.



up to 50μ in length, and bear from 3 to 6 secondary sterigmata 10-12μ long. The chains of conidia are sometimes branched and consist of almost smooth or unconspicuously roughened, globose to elliptical spores from 3 to 4μ in diameter along their axis. Sclerotia are produced abundantly and average 500μ in diameter.

In addition to the Aspergilli, there are at least three species of the Mucoraceae found in or on wet cacao-beans in this country.

### IIe. Circinella spinosa Van Tieg. et Le Monn.

(Plates VII, fig. 17, VIII, fig. 9, XIII, fig. 2).

A few samples of mouldy beans which had been purchased by small buyers were found to be infected by a grey brown mould which developed rapidly in a damp chamber covering the surface of the beans, and filling the interstices between the cotyledons. On Dox agar the mould, at first white, grew luxuriantly filling the tube with a floccose, light brown olive (R.XXX.19″.k.) growth of sporangiophores.

The sporangiophores consist of sympodia of circinnate pedicels bearing spherical sporangia.

The sporangiophores vary considerably in width (7-16 μ) and are indefinite in length, as may be seen by figure 2 on Plate XIII. They arise from a sturdy mycelium which bears numerous delicate rhizoid branches (fig 4). The sporangiophores are at first hyaline but in a few weeks they assume a cinnamon buff colour (R.XXIX.17″.b.) and may be incrusted with minute crystals.

The pedicels are always recurved at the upper end; a septum is formed below the recurved portion, and below the septum the next pedicel is developed. The system of branching is thus usually a simple one. Sporangia are spherical, hyaline cream or clay colour (R.XXIX.17″.), they have persistent walls and measure from 30 to 90 μ in diameter. The columella is variable in shape from cylindrical to pyriform, sometimes almost spherical, hyaline to buff, and 25–80 X 12–57μ in size. The spores are hyaline smooth, spherical or subglobose, 3–6μ in diameter.

Zygospores have not been found.

Cultures of the fungus were sent by the Imperial Bureau of Mycology to Professor Lendner, who kindly provided the definite diagnosis.

(*C. spinosa* is found in Europe on the excrement of man, horses and rats.)

### IIf. Absidia regneri (Lucet et Const.) Lendner.

(Plates VII, fig. 16, VIII, fig. 8, XII, fig. 2),

A white mould which has been found once or twice on beans prepared for export occurs as both an external and internal infection. It develops rapidly at a temperature of 40°C. and was originally found in beans which contained 24 per cent. of moisture. In culture the growth produced was floccose, white and abundant, on cacao-beans the mould appeared to be slightly coloured.

The sporangiophores are slender, not exceeding 12μ in width, they tend to become tinted and, on some media, are minutely echinulate at the apical end. The method of branching is diverse ; a main axis, terminating in a sporangium, may produce single erect pedicels below a septum, short apparently hypertrophied sympodia of circinnate pedicels, or a verticillate arrangement of straight pedicels. The pedicels are usually more slender than the axis on which they are borne, and are somtimes septate; they enlarge at their apices into a funnel or cup-shaped apophysis which supports the spherical sporangium. The sporangia are colourless and usually completely diffluent, those illustrated by fig. 8 of Plate VIII appeared dark at the magnification at which they were drawn possibly owing to the inclusion of air. The columella is smooth, delicate, sometimes collapsing into the apophysis, oval in vertical section and usually depressed, its height never exceeding its width. The spores are hyaline, oblong to irregularly spherical, smooth, measuring 3–9 X 2.5–5μ, or from 3–7.5μ in diameter when nearly spherical.

Zygospores have not been found.

The interest of this fungus lies in its thermophilic tendency as a possible invader of fermenting heaps.

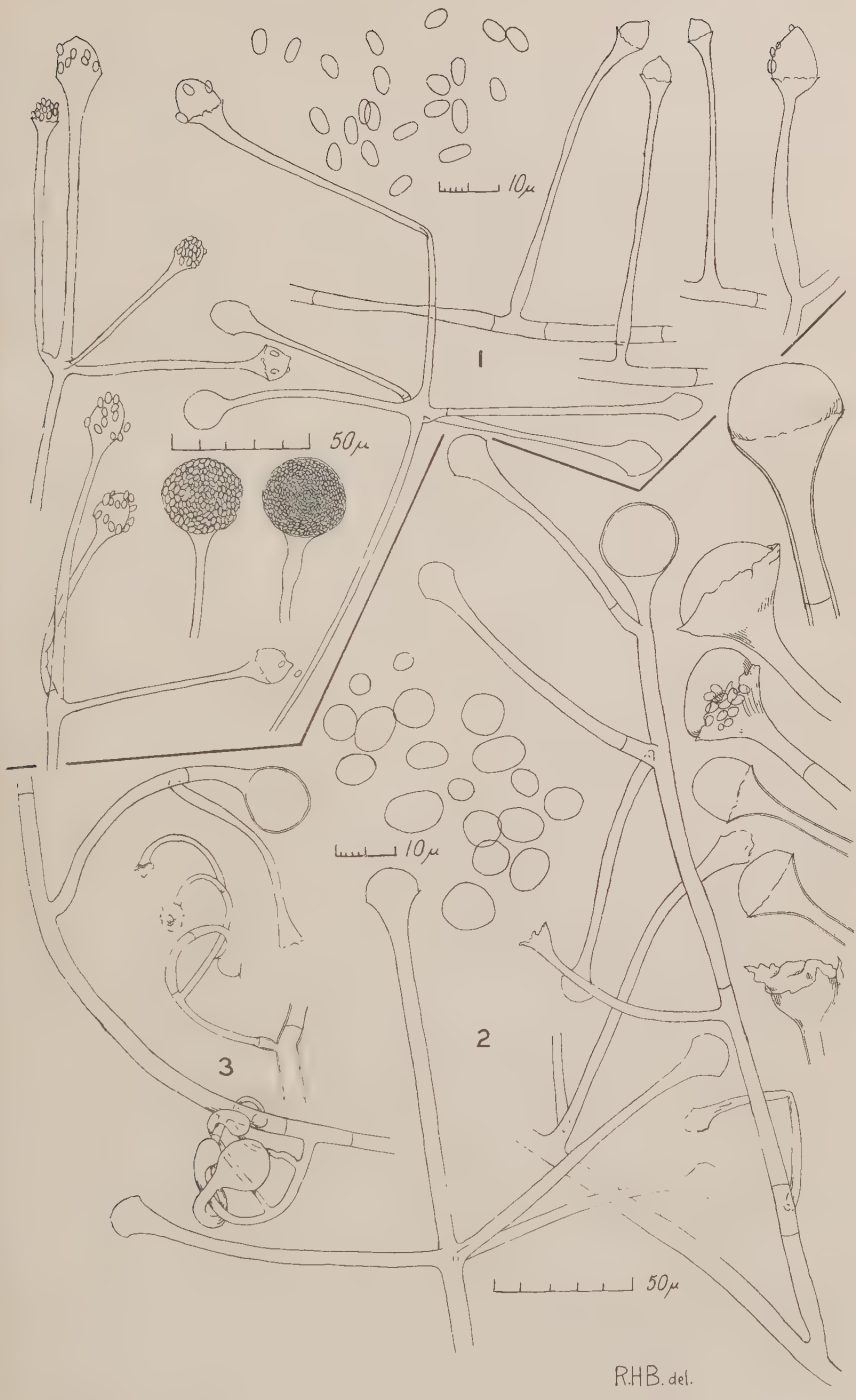
Professor Lendner, in correspondence with the Imperial Bureau of Mycology, advises the adoption of the binomial *A. regneri* for this fungus. He states (" Les Mucorinées de la Suisse, " 1908) that *A. regneri* does not grow at a temperature of 51–52°C, but that the nearly related *A. truchisi* (Lucet et Const.) does grow at that temperature. Both are pathogenic to the rabbit.

### IIg. Absidia capillata Van Tieg.

(Plate XII, fig. 1).

A second species of the genus Absidia has been found on the surface of fermented cacao-beans during the early stages of the drying process. The fact that the infected beans contained 38. 5 per cent. of moisture probably accounts for the fungus not being known to occur within dry produce.

# Plate XII.



This species of *Absidia* differs from the preceding one by its more slender proportions, its sporangiophores rarely exceed 7μ in width, its spores are also smaller and more uniformly oblong in shape, and the height of its columella is equal to, or frequently exceeds the width

It produces a white, floccose, growth in culture which rapidly fills the tube with an aerial fertile mycelium. The sporangiophore branches apically with a verticillate arrangement of long fragile, straight pedicels; simple pedicels may also arise below a septum on the main axis, and are sometimes slightly swollen at or near their junction with the sporangiophore. The sporangia are colourless spherical and diffluent, 16 to 30μ in diameter. The columella is typically conical, sometimes mammiform, and occasionally oval. The spores are oblong, hyaline and smooth, 4.5–5.5 x 2–3μ.

No zygospores have been found.

Professor Lendner has kindly provided the diagnosis of this species. It is found in Europe on the excrement of the horse.

## III. MOULDS OCCURRING ON COMMERCIALLY DRY CACAO BEANS.

From an economic point of view the most important fungi that infect the interior of cacao-beans are those which persist under conditions of relative dryness. It is unfortunate that, no satisfactory standard of dryness having been fixed, a definition of commercial dryness is impossible. The practice at present adopted by producer and purchaser to judge dryness is by touch, a method of obvious inexactitude and one which has been shown to give results varying from 4.5 to more than 9% of moisture in beans examined by experienced men. Moreover by this means no account can be taken of the relative moisture content of embryo and testa.

Our attempts to ascertain the minimum amount of moisture necessary in any part of a fermented cacao-bean to develop, or maintain, the growth of moulds, have not been concluded. They have been complicated, first by the ever varying moisture content of the bean in its reaction to atmospheric moisture, and again by the number of moulds which occurred. The result of such work as has been accomplished on moisture absorption and its relation to the development of moulds are given in previous papers and it will suffice here to state that an effort to classify cacao

moulds has singled out the fungus described below as the mould which requires the least amount of moisture for its maintenance. For this reason, and because of the fact that it is capable of penetrating the testa of a bean (see p. 47), it is considered as the most important mould in cacao beans, and as the subject for continued study.

### IIIa. Aspergillus glaucus group.

(Plates VII, figs. 1, 2, and 3, VIII, fig. 4, IX, figs 1, 2, and 3).

It is significant that the only species of *Aspergillus* affecting cacao-beans to which reference can be found in literature is a conidial form which Thom and Church (p. 118) consider to be a member of this group. *A. delacroixii* Sacc. and Syd. is reported *in sinubus cotyledonum seminis* in Columbia (Saccardo. 14.1044–45); as causing *maladie du vice propre* in equinoctial America and the West Coast of Africa (*d*) as well as on diseased cacao pods in the Philippine Islands (*e*).

The fungus as it occurs locally in fermented cacao-beans appears either as a deep bluish glaucous (R. XLII. 37″ .d) mass of spore heads (Plate VII, fig. 2), as a pinhard yellow (R. IV. 21.d) collection of perithecia (fig. 3), or as combinations of those colours differing in hue according to the proportion of perithecia scattered among the conidia (fig. 1).

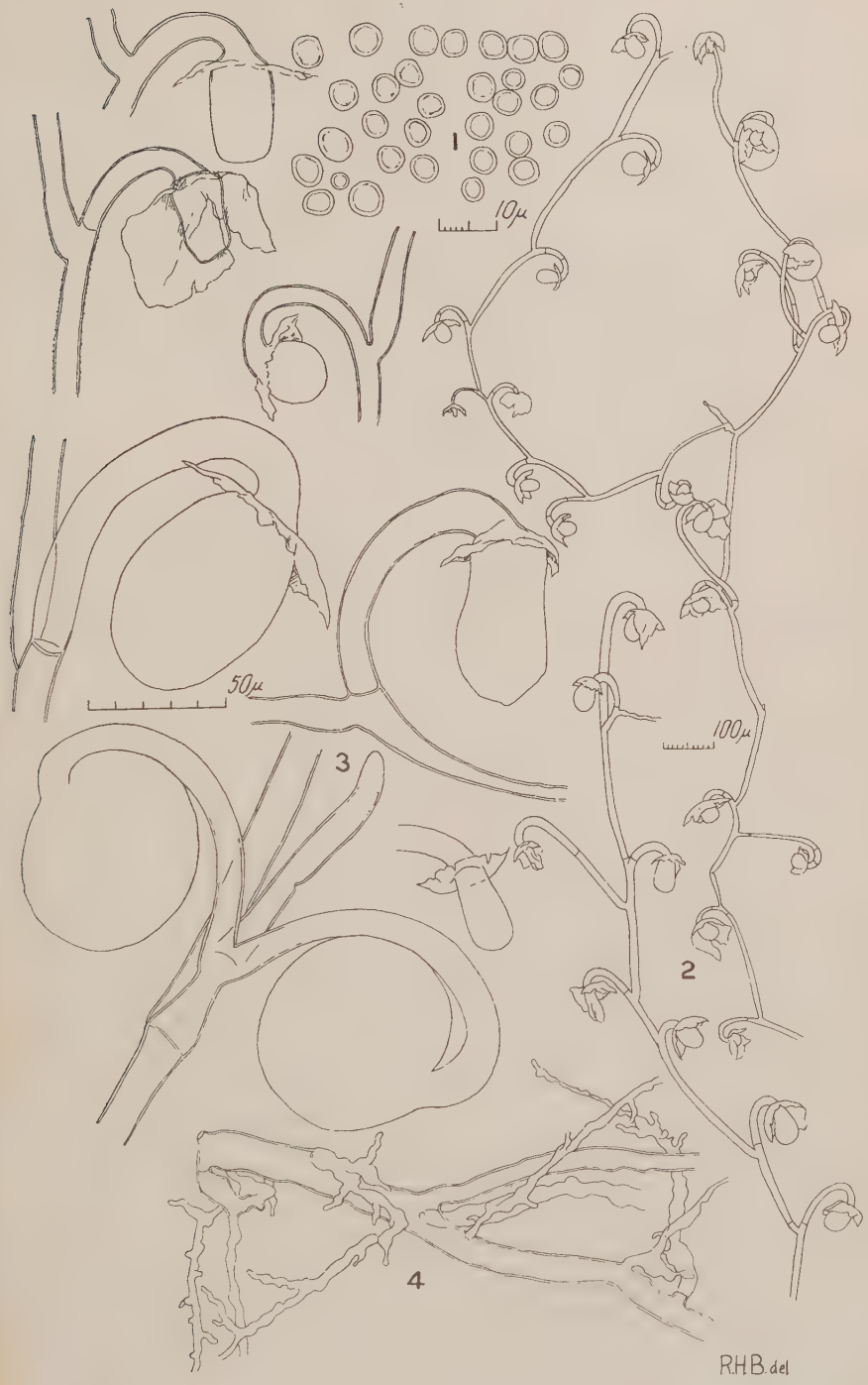
The occurrence of a perithecial stage distinguishes this species from all other forms of *Aspergillus* in cacao-beans. The conidial stage most closely approaches that of A. *fumigatus* in colour and by having a single series of sterigmata; it differs from the latter in sporophores and spores.

The spore heads are at first white, changing from yellow to glaucous blue, and in old growths assuming an olivaceous colour. They are borne on smooth, usually septate, sporophores which increase in width from 6–13μ at the base to 9-19μ at the insertion of the vesicle. The vesicle may be almost spherical and up to 100μ in diameter, or slightly more than twice the diameter of the upper part of the stalk. The simple sterigmata measures from 7-14 x 3-4μ, and occupy practically the whole surface of the vesicle. In culture they tend to proliferate into fantastic forms giving rise to branches which may become sporiferous vesicles, sterile out-growths, or ascogenous hyphae (Plate IX, fig. 2). The conidia are oval to globose, minutely verrucose, 4–7 x 3.5–6μ. The bright yellow perithecia are spherical, from 60 to 120μ in diameter, and arise direct from

(*d*) Delacroix & Maublanc: Maladies des Plantes cultivees dans les Pays Chauds, p. 472.

(*e*) Reinking in Phytopathology V. 9. p. 138.

Plate XIII.



the recumbent aerial mycelium, they contain a number of irregularly obovate to oval perithecia containing eight spores and measuring 13–17 x 10–12μ. The ascospores are colourless lens-shaped, 3–4.5 x 2.5 3.5μ, with two projecting flanges bordering a median furrow (fig. 3).

The small size of the ascospores precludes the consideration of this fungus as a form of *Eurotium herbariorium* Link. It is probably the organism referred to by Thom and Church (p III) as *A. chevalieri* (Mangin), but efforts to obtain cultures of the latter species for comparison have been unsuccessful, and a critical determination is therefore not yet possible.

### IIIb. Penicillium sp.

(Plates VII, figs. 12 and 13, VIII, fig. 11).

Occasionally dry cacao-beans stored under damp conditions become infested by a *Penicillium* which is shown in figure 12 of Plate VII entering the testa by means of the orifice caused by the germinating radicle.

The fungus produces in culture velvety colonies that are slate olive (R. XLVII 29″″ i.) in the centre and diminish in tone to a white border. In old cultures of Dox agar it becomes uniformly mummy-brown in colour (R. XV 17′ .m). It bears from two to four sterigmata on the somewhat swollen apices of the branched sporophore; the sterigmata measure 7–15 x 2.5–5μ, and give rise to chains of conidia which may be up to 200μ in length.

The conidia are spherical, smooth, light-green, 2–5μ in diameter in young colonies, and 2–3μ when produced by older growths; in the accompanying figure the spores on the right are from a three months' old culture, the others from a younger growth.

## PAPER No. IX.

# PRELIMINARY OBSERVATIONS ON THE MOISTURE CONTENT AND HYGROSCOPICITY OF CACAO BEANS.

By J. L. SCOTT.

Recent research into moulds attacking local cacao beans has made the question of moisture content and hygroscopicity of this product an important one. This paper is the result of an investigation into the subject and while it pretends neither to give a complete survey of moisture contents of Gold Coast cacao, nor to give a final verdict on the effect of storage, it does attempt to portray some facts which have hitherto been unknown. Three questions have been waiting to be solved. They are :—

I. Moisture content of beans straight from the pod.
II. Moisture content of fermented beans before and after drying.
III. Hygroscopic properties of prepared beans

They will be treated under these headings.

## I. MOISTURE CONTENT OF BEANS STRAIGHT FROM THE POD.

Ten cacao pods were taken from different trees growing in Aburi Gardens. Samples were taken from each pod and their moisture contents determined. The following table gives the results obtained.

| Sample No. | Type of Pod. | Moisture %. |
|---|---|---|
| 1 .. .. .. | Amelonado .. | 51.1 |
| 2 .. .. .. | ,, | 52.3 |
| 3 .. .. .. | ,, | 49.3 |
| 4 .. .. .. | ,, | 50.8 |
| 5 .. .. .. | ,, | 50.6 |
| 6 .. .. .. | ,, | 49.6 |
| 7 .. .. .. | Criollo (red) .. | 57.8 |
| 8 .. .. .. | Criollo (yellow) .. | 60.6 |
| 9 .. .. .. | Cundeamor .. | 60.9 |
| 10 .. .. .. | Ocumare .. .. | 54.2 |
| Total .. .. .. | | 537.2 |
| Average .. .. .. | | 53.7 |
| Average for Amelonado | | 50.6 |
| Average for Others .. | | 58.4 |

It is interesting to note that the Amelonado beans have a lower average moisture content than have the other types tested.

## II. MOISTURE CONTENT OF FERMENTED BEANS.

### a. Immediately after fermenting.

Three samples were taken from different batches in the Aburi Gardens. The results are as follows :—

| Sample No. | Type. | Moisture content. |
|---|---|---|
| | | % |
| 1 .. .. | Amelonado .. .. | 46.5 |
| 2 .. .. | ,, | 45.3 |
| 3 .. .. | ,, | 45.5 |
| Average .. .. | — | 45.8 |

### b. At different periods during drying.

Samples from the same drying beans were examined after four, six and eight days.

| Period of drying. | Moisture content. |
|---|---|
| | % |
| Straight from heaps .. .. | 45.3 |
| After 4 days .. .. .. | 20.9 |
| ,, 6 ,, | 11.3 |
| ,, 8 ,, | 6.2 |

These figures must vary a great deal with varying condition of sun and relative humidity. (*See* also drying curves in Dade's Paper No. X).

### c. Survey of moisture content of finished cacao.

**Cacao on the Accra Beach.**

During the year 1928 periodical analyses were made of samples obtained from consignments awaiting shipment on the Accra beach. The samples were conveyed from beach to laboratory in weighing bottles so that no change in moisture content could take place

Only eight weighing bottles were available and eight samples were taken during each of the months tabulated below. In July one bottle was broken and only seven samples were taken during that month.

| January 1928. | | March 1928. | | April 1928. | | July 1928. | |
|---|---|---|---|---|---|---|---|
| Sample No. | Moist. %. | Sample No. | Moist. %. | Sample No. | Moist. %. | Sample No. | Moist. %. |
| 1 | 7.5 | 9 | 6.5 | 17 | 9.9 | 25 | 9.5 |
| 2 | 7.5 | 10 | 6.0 | 18 | 6.3 | 26 | 9.6 |
| 3 | 8.4 | 11 | 6.7 | 19 | 6.4 | 27 | 10.2 |
| 4 | 10.6 | 12 | 9.1 | 10 | 5.9 | 28 | 12.8 |
| 5 | 8.0 | 13 | 7.6 | 21 | 5.6 | 29 | 10.4 |
| 6 | 7.9 | 14 | 7.4 | 22 | 5.5 | 30 | 9.1 |
| 7 | 8.7 | 15 | 7.6 | 23 | 5.5 | 31 | 10.7 |
| 8 | 9.3 | 16 | 6.9 | 24 | 6.0 | — | — |
| Total | 67.9 | Total | 57.8 | Total | 51.1 | Total | 72.3 |
| Av. | 8.5 | Av. | 7.2 | Av. | 6.4 | Av. | 10.3 |

It is demonstrated in Paper No. X of this Year Book that cacao containing less than 8% moisture is not likely to develop mould, while beans containing more than 8% moisture are in the danger zone. In 13 out of 31 samples taken at Accra the moisture content was 8% and over. The cacao tested during March and April was taken from consignments prepared during February and March—two dry months. Note the comparatively low moisture content. The samples examined during January and July represent cacao prepared in December and June. More rain fell in December 1927 than in January and February 1928, and June is one of the wettest months in the year.

**Cacao from different centres.**

The remaining samples were obtained during the month of December 1928 except in the case of Koforidua where samples were taken in January, 1929.

The number of samples taken from places other than Aburi was limited by the number of weighing bottles available. In all cases samples were obtained from different firms and may be considered fairly representative.

**Cacao from Aburi Gardens prepared by Government.**

Ten samples were taken from Aburi Gardens. The results are as follows :—

| Sample No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Moisture %. | 7.0 | 6.7 | 6.9 | 7.1 | 6.9 | 6.6 | 6.8 | 7.1 | 7.0 | 6.5 | 68.6 | 6.9% |

The samples were taken from cacao which had been dried in the sun for eight days and may be considered well dried.

**Aburi Farmers' Cacao.**

Thirty samples were taken at odd periods throughout the month from Aburi merchants. The cacao sampled was representative of cacao prepared in the Aburi district.

ABURI FARMERS' CACAO.

| Sample No. | Moisture %. | Remarks. |
|---|---|---|
| 1 | 6.9 | Just received from farmer. |
| 2 | 6.5 | ,, ,, ,, ,, |
| 3 | 7.4 | ,, ,, ,, ,, |
| 4 | 6.6 | ,, ,, ,, ,, |
| 5 | 9.9 | ,, ,, ,, ,, |
| 6 | 7.4 | Ready for transfer to Accra. |
| 7 | 7.0 | ,, ,, ,, ,, |
| 8 | 9.3 | ,, ,, ,, ,, |
| 9 | 9.5 | ,, ,, ,, ,, |
| 10 | 7.9 | Just received from farmer. |
| 11 | 7.3 | ,, ,, ,, ,, |
| 12 | 8.3 | ,, ,, ,, ,, |
| 13 | 8.3 | ,, ,, ,, ,, |
| 14 | 7.6 | ,, ,, ,, ,, |
| 15 | 8.1 | Ready for transfer to Accra. |
| 16 | 5.7 | ,, ,, ,, ,, |
| 17 | 7.6 | ,, ,, ,, ,, |
| 18 | 8.8 | ,, ,, ,, ,, |
| 19 | 9.8 | ,, ,, ,, ,, |
| 20 | 8.3 | ,, ,, ,, ,, |
| 21 | 8.3 | ,, ,, ,, ,, |
| 22 | 7.3 | ,, ,, ,, ,, |
| 23 | 6.5 | ,, ,, ,, ,, |
| 24 | 7.7 | ,, ,, ,, ,, |
| 25 | 11.4 | Just received from farmer. |
| 26 | 14.0 | ,, ,, ,, ,, |
| 27 | 6.8 | ,, ,, ,, ,, |
| 28 | 7.4 | ,, ,, ,, ,, |
| 29 | 7.2 | ,, ,, ,, ,, |
| 30 | 7.9 | Ready for transfer to Accra. |
| Total .. .. .. | 242.7 | |
| Average .. .. | 8.1 | |

It will be observed that none of this cacao is extremely wet. Twelve samples, however, contain more than eight per cent. moisture

**Cacao from other centres.**

Samples were obtained from Winneba, Saltpond, Sekondi, Kumasi and Koforidua. The results are tabulated below :—

| Winneba. | | Saltpond. | | Sekondi. | | Kumasi. | | Koforidua. | |
|---|---|---|---|---|---|---|---|---|---|
| Sample No. | Moist. %. | Sample No. | Moist. %. | Sample No. | Moist. %. | Sample No. | Moist. %. | Sample No. | Moist. %. |
| 1 | 8.6 | 1 | 5.6 | 1 | 8.5 | 1 | 6.8 | 1 | 8.8 |
| 2 | 8.1 | 2 | 6.1 | 2 | 8.4 | 2 | 10.2 | 2 | 7.8 |
| 3 | 8.5 | 3 | 7.4 | 3 | 7.5 | 3 | 7.5 | 3 | 10.3 |
| 4 | 8.3 | 4 | 5.9 | 4 | 8.0 | 4 | 6.8 | 4 | 8.5 |
| 5 | 10.9 | 5 | 5.9 | 5 | 7.5 | 5 | 10.5 | 5 | 7.4 |
| 6 | 8.1 | 6 | 6.3 | 6 | 8.0 | 6 | 6.7 | 6 | 8.6 |
| 7 | 8.9 | 7 | Spoilt | 7 | 7.7 | 7 | 9.5 | 7 | 8.5 |
| Total | 61.4 | Total | 37.2 | Total | 55.6 | Total | 58.0 | Total | 59.9 |
| Av. .. | 8.8 | Av. | 6.2 | Av. | 7.9 | Av. | 8.3 | Av. | 8.6 |

These results are very interesting. Out of thirty-five samples taken from different centres 19 contain more than eight per cent. of moisture which places them inside Dade's mould danger zone.

Five contain more than 9.5 per cent. moisture which means that they will certainly grow mouldy. Considering that these results were obtained during December, a dry month, they are disturbing.

## III. THE HYGROSCOPIC PROPERTIES OF CACAO BEANS.

In comparison with other cacao growing countries the Gold Coast has a relatively low rainfall. A perusal of figures of rainfall would not lead an observer to expect that it is the world's greatest cacao producing centre. It is well-known, however, that lack of rain is compensated by a very high relative humidity. This has its disadvantages ; it is not conducive to the production of well dried cacao and, although farmers might easily dry their cacao much more thoroughly than they do, as a comparison between Government cacao and commercial cacao will show, it has never been proved that even well dried beans cannot absorb sufficient moisture from the atmosphere to grow mould.

Merchants and farmers alike often store their produce for long periods of time. Although the cacao is kept in bags in buildings of various types, it is suspected that if cacao is very hygroscopic even these protections are not proof against the absorption of atmospheric moisture. A study of the actual hygroscopic properties of the bean itself must form the basis of all investigation into the subject. Future work of a wider and more commercially useful nature will be guided by the information gained from these primary experiments.

## IV. EXPERIMENTS SHOWING HYGROSCOPIC PROPERTIES OF CACAO BEANS.

### a. Absorption of moisture by the bean.

The relative humidity of the atmosphere at Aburi is not steady. Except during the severe drought of the harmattan it varies from approximately 60 to 98 R.H. in the course of an ordinary day. It is therefore not the place in which the cacao beans' capacity for absorbing moisture can be easily observed. The expedient was resorted to of making atmospheres of known relative humidity. Using caustic potash according to Wuhlner, atmospheres of 75, 80, 85, 90 and 95 R.H. were made in shallow, airtight, glass dishes. Each atmosphere was tested by means of wet and dry bulb thermometers. Certain weights of cacao containing 6.2 per cent. of moisture were placed in these chambers and weighed daily until equilibrium was reached. Wire gauze receptacles were used for the beans so as to offer the least resistance to the atmosphere.

It must be noted that the beans, by absorbing moisture must, to a certain extent, have changed the atmospheres in which they were placed. This change was calculated at the end of the experiment and found to be negligible. The table below gives figures showing the behaviour of the cacao in these atmospheres :—

| | R.H. 75 | R.H. 80 | R.H. 85 | R.H. 90 | R.H. 95 |
|---|---|---|---|---|---|
| Original Moisture % | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 |
| After 1 Day .. | 6.7 | 7.0 | 7.6 | 9.2 | 10.6 |
| „ 2 Days .. | 6.9 | 7.4 | 8.1 | 10.2 | 12.3 |
| „ 3 „ | 7.1 | 7.6 | 8.4 | 10.9 | 13.6 |
| „ 4 „ | 7.2 | 7.7 | 8.5 | 11.2 | 14.4 |
| „ 5 „ | 7.3 | 7.7 | 8.6 | 11.4 | 15.1 |
| „ 6 „ | 7.3 | 7.7 | 8.7 | 11.6 | 15.3 |
| „ 7 „ | 7.3 | 7.7 | 8.7 | 11.6 | 15.5 |
| „ 8 „ | 7.3 | 7.7 | 8.7 | Loss of wt. | Loss of wt. |
| „ 9 „ | 7.3 | 7.7 | 8.7 | „ | „ |

In atmospheres of 90 and 95 R.H. mould appeared on the surface of the beans at moisture contents of 11.6 per cent. and 15.3 per cent. respectively. Neither of these samples remained at equilibrium—both started to lose weight because of decomposition setting in.

Plate No. XIV gives the absorption curve for this experiment. It will be observed that :—

1. Cacao beans are extremely hygroscopic.
2. Placed in atmospheres of 75, 80, 85, 90 and 95 R.H. normally dry cacao beans come to equilibrium with moisture contents of 7.3, 7.7, 8.7, 11.6 and 15.5 per cent.

3. The farther the beans are from the equilibrium point the greater will be the rate of absorption. The nearer they are the quicker will be the approach to equilibrium.

4. In all cases, even in the atmosphere of 95 R.H. where the beans absorbed 9.3 per cent. of moisture, the beans had come to within one per cent. of equilibrium after four days.

### b. Loss of moisture by the bean.

Using similar atmospheres of 75, 80, 85, 90 and 95 R.H. the capacity of the bean for losing moisture was tested. Some difficulty was met with in obtaining beans wet enough for the purpose and finally beans much affected by moulds and containing 23.8% of moisture were used. The presence of moulds on the beans introduced a new factor in that excretions were present which probably had an effect on the atmosphere. It is likely that a bean covered with mould is a different thing hygroscopically from a bean without mould. For that reason the equilibrium figures obtained in this experiment cannot be considered reliable. They are nevertheless useful in that they demonstrate the general principles of dehydration.

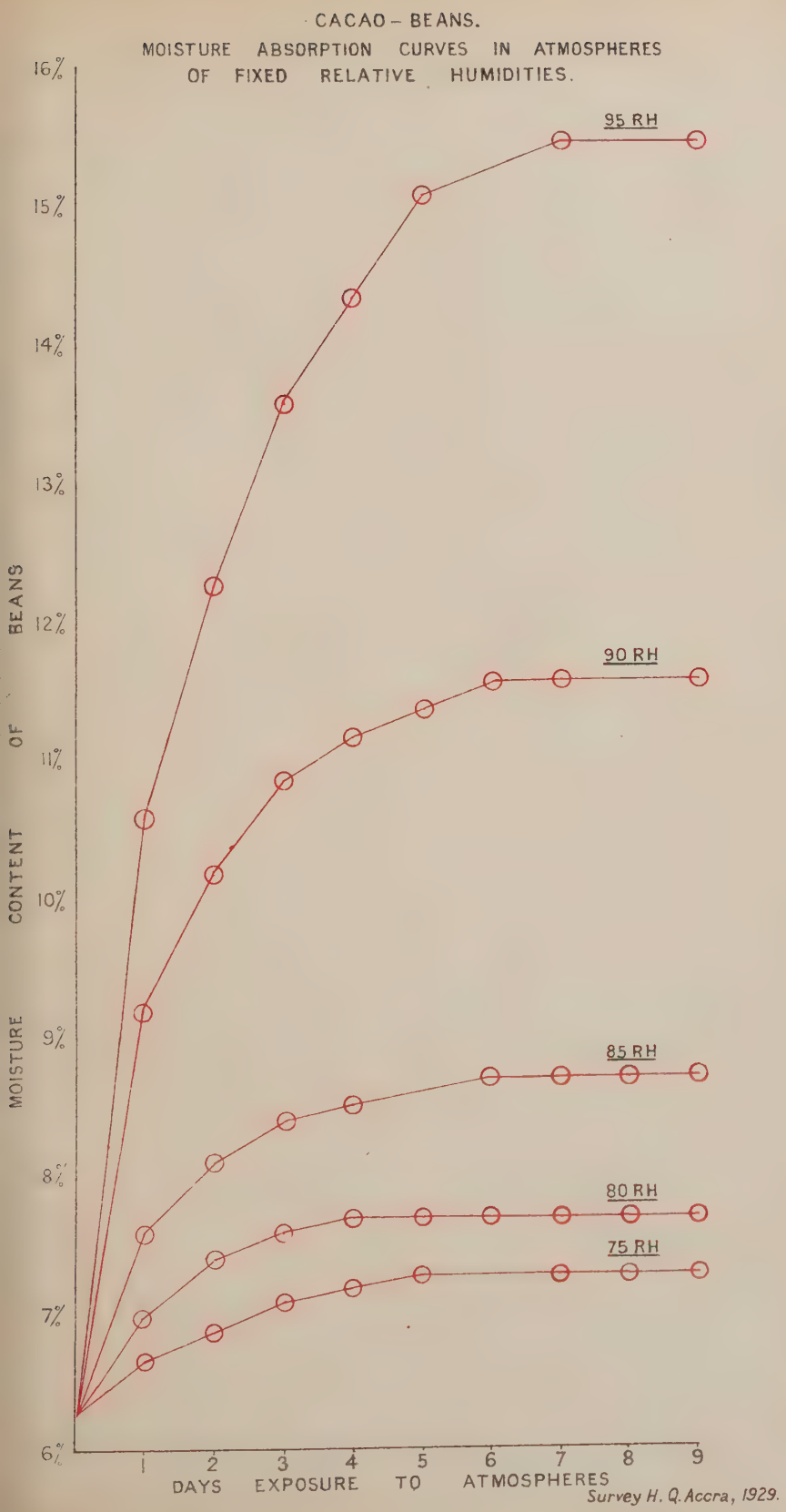
The table below gives the results obtained :—

| | R.H. 75 | R.H. 80 | R.H. 85 | R.H. 90 | R.H. 95 |
|---|---|---|---|---|---|
| Original moisture % | 23.8 | 23.8 | 23.8 | 23.8 | 23.8 |
| After 1 day .. .. | 15.6 | 17.2 | 18.4 | 20.4 | 22.4 |
| „ 2 days .. .. | 11.3 | 13.4 | 15.2 | 17.0 | 21.0 |
| „ 3 „ | 9.1 | 11.2 | 13.3 | 16.0 | 19.5 |
| „ 4 „ | 8.1 | 10.1 | 12.2 | 14.7 | 18.2 |
| „ 5 „ | 7.7 | 9.4 | 11.5 | 13.8 | 17.2 |
| „ 6 „ | 7.4 | 9.2 | 11.3 | 13.4 | 16.4 |
| „ 7 „ | 7.2 | 9.0 | 11.0 | 12.9 | 15.7 |
| „ 8 „ | 7.1 | 8.7 | 10.9 | 12.6 | 15.6 |
| „ 9 „ | 7.0 | 8.6 | 10.7 | 12.3 | 14.7 |
| „ 10 „ | 7.0 | 8.6 | 10.6 | 12.2 | 14.2 |
| „ 11 „ | 7.0 | 8.5 | 10.5 | 11.9 | 13.8 |
| „ 12 „ | 7.0 | 8.5 | 10.5 | 11.8 | — |
| „ 13 „ | 7.0 | 8.5 | 10.5 | 11.8 | — |

Plate No. XV shows the curves for this experiment. The moulds in the 90 R.H. and 95 R.H. samples increased. In the 95 R.H. the sample lost weight steadily until an equilibrium of 15.6% appeared to be reached. The next day however there was a sudden drop, which was probably caused by decomposition setting in.

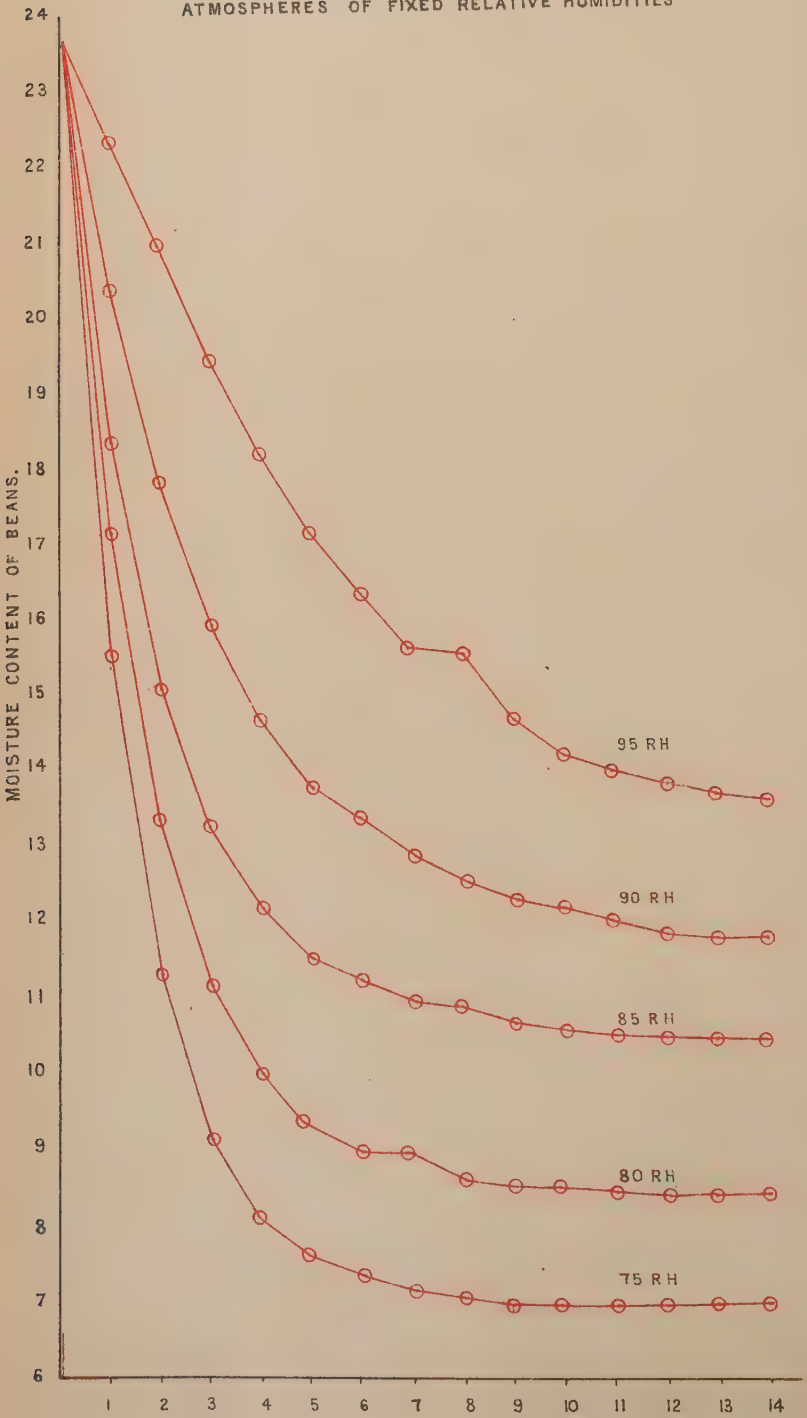
The equilibrium points in the samples placed in the 80 and 85 R.Hs. were different from those obtained in the absorption

Plate XIV


CACAO – BEANS.
MOISTURE ABSORPTION CURVES IN ATMOSPHERES OF FIXED RELATIVE HUMIDITIES.
95 RH
90 RH
85 RH
80 RH
75 RH
MOISTURE CONTENT OF BEANS
16%
15%
14%
13%
12%
11%
10%
9%
8%
7%
6%
1
2
3
4
5
6
7
8
9
DAYS EXPOSURE TO ATMOSPHERES
Survey H. Q. Accra, 1929.

CACAO BEANS

MOISTURE EVAPORATION—CURVES IN ATMOSPHERES OF FIXED RELATIVE HUMIDITIES



experiment. They are probably wrong and will not be used in this paper. Certain facts remain however.

They are :—

1. Cacao beans lose moisture as easily as they gain it. The rate of absorption is probably similar to the rate of dehydration.
2. No matter how wet cacao beans may be they will come to equilibrium with whatever stable atmosphere they are in. The further is the moisture content above the moisture content of equil.brium the quicker will be the loss of moisture.
3. Again, as in the absorption experiment, all beans in all atmospheres had come to within 1% of equilibrium within four days.

### c. Probable moisture content of cacao in equilibrium with any atmosphere.

It has already been observed that the points of equilibrium of the samples in the two types of experiment do not coincide for similar atmospheres. It must be remembered that each experiment was carried out only once and, before any definite conclusion would be arrived at, each would require to be repeated.

The samples in the experiment described in the foregoing section were not satisfactory. They were covered with moulds and had probably ceased to have the same hygroscopic properties as normal cacao beans. Trials on absorption however may be considered fairly satisfactory, since the beans were well dried and normal in every way. The equilibrium points may therefore be taken as approximately correct Using these points obtained in the latter it will be possible to draw a curve which will be a guide to the approximate moisture contents of cacao in equilibrium with any stable atmosphere between 75 and 95 R.H.

This will be seen in Plate No. XVI. It will be profitable to compare the data thus obtained with the behaviour of cacao beans exposed to the fluctuating atmospheric conditions at Aburi.

## V. EXPERIMENTS ON STORED CACAO.

### a. Cacao exposed in Aburi Garden cacao store.

Aburi is one of the most humid places in the Gold Coast. The relative humidity has a very wide range but except during the harmattan it has a high average which does not vary much.

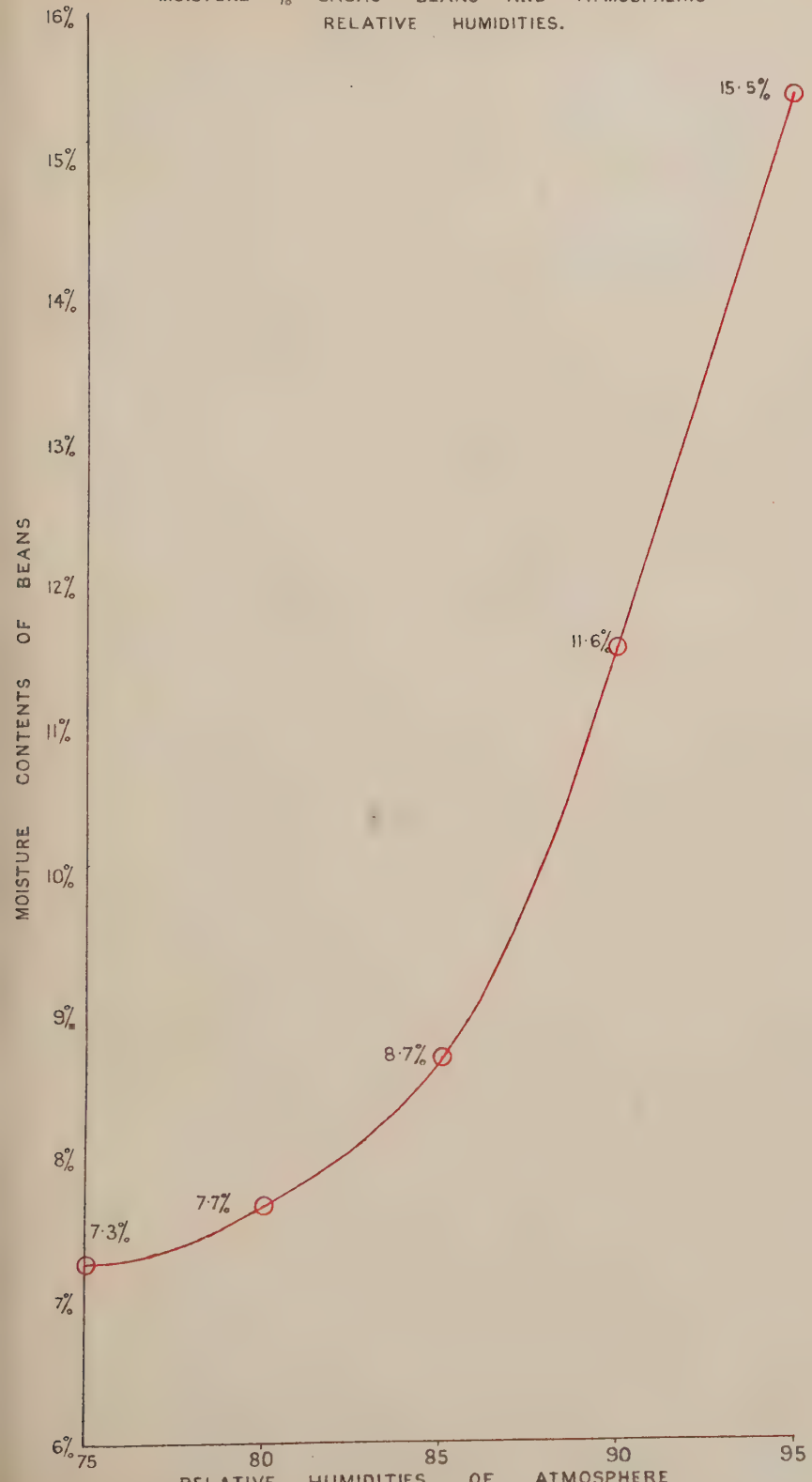
This experiment was carried out during December, that month of transition, during which the rains have not quite gone and the harmattan is just beginning to make its presence felt. It may therefore be considered a most excellent time for observing the behaviour of cacao beans in a fluctuating atmosphere.

One hundred cacao beans which had been dried in the sun to 5.6% moisture content were weighed out into a dish and exposed to the atmosphere in the Aburi Garden cacao store. The relative humidity of the atmosphere was recorded by an Edney Hair Hygrometer which was regularly adjusted and checked by wet and dry bulb thermometers and found to be accurate. The cacao was weighed at 8 a.m., 12 noon and 4 p.m. during a period of 24 days, i.e., 30th November—23rd December and the moisture percentages calculated.

During the period under observation there was no distinct change in the general atmospheric conditions, but the fluctuations during each day were great. The following table gives the four hourly relative humidities and the daily moisture contents of the cacao during that period :—

| Date. | 12 mid-night. | 4 a.m. | 8 a.m. | 12 noon. | 4 p.m. | 8 p.m |
|---|---|---|---|---|---|---|
| 30th Nov., R.H. .. | — | — | — | 70 | 75 | 90 |
| M.% .. | | | | | 5.6 | |
| 1st Dec., R.H. .. | 92 | 94 | 95 | 76 | 72 | 86 |
| M.% .. | | | 6.4 | 6.3 | 5.9 | |
| 2nd Dec., R.H. .. | 92 | 94 | 96 | 70 | 67 | 88 |
| M.% .. | | | 6.4 | 6.2 | 6.0 | |
| 3rd Dec., R.H. .. | 91 | 92 | 94 | 76 | 75 | 88 |
| M.% .. | | | 6.5 | 6.4 | 6.2 | |
| 4th Dec., R.H. .. | 78 | 90 | 91 | 63 | 85 | 94 |
| M.% .. | | | 6.6 | 6.5 | 6.1 | |
| 5th Dec., R.H. .. | 94 | 94 | 96 | 72 | 73 | 90 |
| M.% .. | | | 6.7 | 6.6 | 6.4 | |
| 6th Dec., R.H. .. | 94 | 95 | 92 | 62 | 70 | 90 |
| M.% .. | | | 7.1 | 6.9 | 6.6 | |
| 7th Dec., R.H. .. | 92 | 94 | 92 | 66 | 72 | 88 |
| M.% .. | | | 7.1 | 6.9 | 6.6 | |
| 8th Dec., R.H. .. | 91 | 92 | 91 | 64 | 66 | 84 |
| M.% .. | | | 7.3 | 7.1 | 7.0 | |
| 9th Dec., R.H. .. | 92 | 93 | 90 | 60 | 68 | 90 |
| M.% .. | | | 7.4 | | 6.9 | |
| 10th Dec., R.H. .. | 90 | 92 | 93 | 64 | 72 | 90 |
| J.% .. | | | 7.5 | 7.1 | 6.7 | |
| 11th Dec., R.H. .. | 90 | 93 | 94 | 70 | 76 | 92 |
| M.% .. | | | 7.3 | 7.2 | 6.7 | |

CURVE SHEWING EQUILIBRIUM – POINTS BETWEEN MOISTURE % CACAO – BEANS AND ATMOSPHERIC RELATIVE HUMIDITIES.




Survey H.Q. Accra, 1929.

| Date. | 12 mid-night. | 4 a.m. | 8 a.m. | 12 noon. | 4 p.m. | 8 p.m. |
|---|---|---|---|---|---|---|
| 12th Dec., R.H. .. | 93 | 94 | 92 | 63 | 72 | 85 |
| M.% .. | | | 7·7 | 7·4 | 7·1 | |
| 13th Dec., R.H. .. | 92 | 94 | 88 | 65 | 70 | 85 |
| M.% .. | | | 7·7 | 7·4 | 7·1 | |
| 14th Dec., R.H. .. | 93 | 94 | 86 | 66 | 74 | 88 |
| M.% .. | | | 7·7 | 7·4 | 7·1 | |
| 15th Dec., R.H. .. | 91 | 94 | 92 | 62 | 70 | 89 |
| M.% .. | | | 7·7 | 7·5 | | |
| 16th Dec., R.H. .. | 92 | 94 | 80 | 62 | 70 | 89 |
| M.% .. | | | 7·7 | | | |
| 17th Dec., R.H. .. | 94 | 94 | 90 | 63 | 70 | 80 |
| M.% .. | | | 7·7 | 7·3 | 7·1 | |
| 18th Dec., R.H. .. | 91 | 92 | 93 | 67 | 70 | 84 |
| M.% .. | | | 7·7 | 7·4 | 7·0 | |
| 19th Dec., R.H. .. | 87 | 94 | 95 | 70 | 76 | 86 |
| M.% .. | | | 7·6 | 7·4 | 7·2 | |
| 20th Dec., R.H. .. | 90 | 95 | 92 | 66 | 66 | 85 |
| M.% .. | | | 7·7 | 7·4 | 7·0 | |
| 21st Dec., R.H. .. | 93 | 93 | 90 | 61 | 75 | 85 |
| M.% .. | | | 7·6 | 7·3 | 7·0 | |
| 22nd Dec., R.H. .. | 94 | 92 | 96 | 58 | 66 | 87 |
| M.% .. | | | 7·8 | 7·3 | 7·0 | |
| 23rd Dec., R.H. .. | 92 | 94 | 93 | 62 | 60 | 90 |
| M.% .. | | | 7·5 | 7·4 | 7·0 | |

It will be observed that cacao beans are very sensitive to the daily fluctuations in relative humidity. During each night the beans gained in moisture content only to lose a percentage of the gain on the ensuing day. The gains predominated over the losses, however, and after a period of 13 days, the moisture content had come to a constant, hovering between 7.1% and 7.7%. This is probably the nearest approach that the beans would ever attain to equilibrium in such an atmosphere. This is clearly demonstrated in Plate No. XVII. The resting point is represented by a series of triangles of equal altitude, all of whose bases form one straight line.

**Moisture content in relation to the dominating atmosphere.**

During the period reviewed in this experiment the general atmospheric conditions remained the same. Each night the relative humidity rose to a more or less equal height and each day fell about an equal distance. By a method of trial it was found that the average of the four-hourly readings on the continuous recording hygrometer gave a figure which seemed to describe the average relative humidity. This average gives a R.H. of 83. Cacao beans in equilibrium with such an atmosphere should have a moisture content of approximately 8.2%. Actually in Experiment 1, they were in equilibrium with a moisture content varying between 7.1% and 7.7%. If it be taken that the equilibrium point is 7.4% moisture there is a difference of 0.8% between the stable and unstable atmospheres. This difference is not big and would seem to indicate that the average obtained acts as a guide to the approximate moisture content to be expected in a fluctuating atmosphere. This fact throws a good deal of light on the actual significance of the daily fluctuations in relative humidity. They would not seem to be of great importance apart from the fact that they are variates in a series of relative humidities whose average gives an expression of the dominating atmosphere. They probably act as breaks which prevent the beans from ever reaching perfect equilibrium.

**Reaction of beans to marked atmospheric changes.**

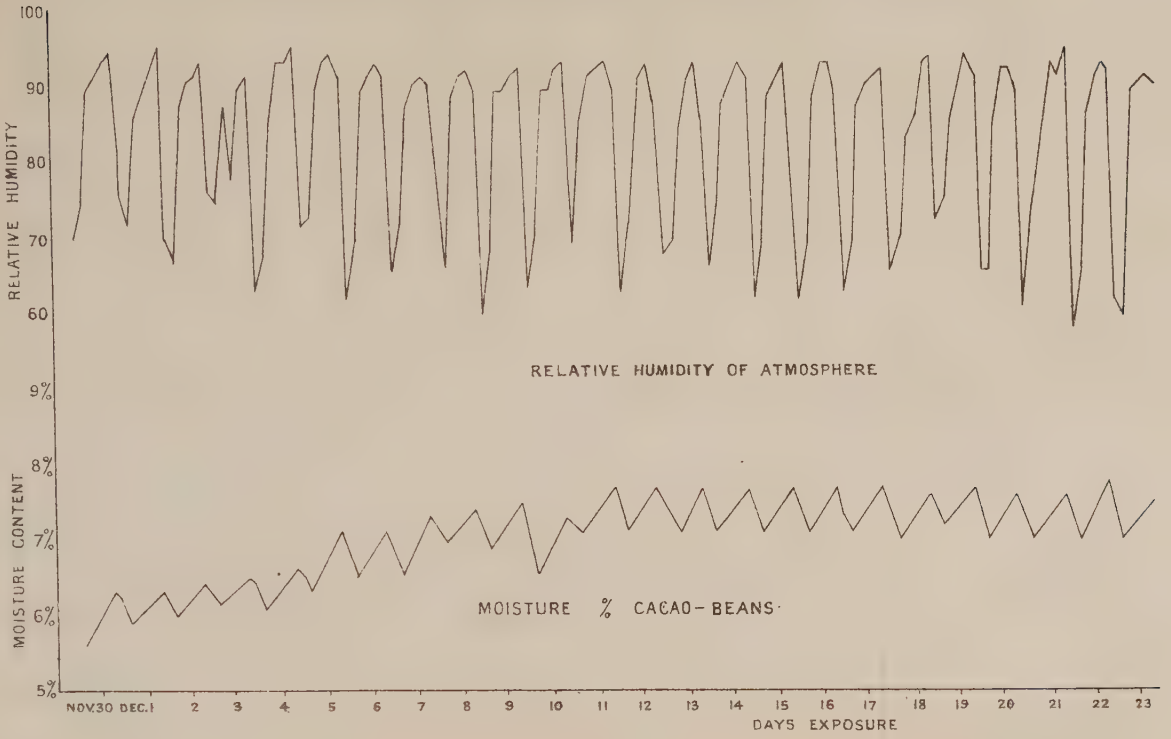
The cacao used in the previous experiment was transferred to an open, gauze-surrounded room at the back of the Aburi laboratory. Here, of course, it was much more exposed and under a different average R.H. and it was expected that a corresponding increase in moisture content would take place. Actually, the very reverse was the case, for on the day after the transfer took place, a very severe harmattan developed. The relative humidity dropped down to a curve ranging from 30 R.H. to 60 R.H. and remained thus for four days.

On the 30th December the harmattan ceased and an average R.H. much higher than that experienced in the store made itself felt. The cacao reacted very quickly to those changes as the following table will show :—

| Date. | 12 midnight. | 4 a.m. | 8 a.m. | 12 noon. | 4 p.m. | 8 p.m. |
|---|---|---|---|---|---|---|
| 24th Dec., R.H. .. | | | | 82 | 84 | 99 |
| Moisture % .. .. | | | 7.4 | 7.5 | | |
| 25th Dec., R.H. .. | 99 | 98 | 96 | 70 | 74 | 89 |
| M.% .. | | | 7.5 | 7.2 | 6.4 | |

Plate XVII

CACAO EXPOSED IN STORE
MOISTURE CHANGE COMPARED WITH CHANGES IN ATMOSPHERIC RELATIVE HUMIDITY.




*Survey H.Q. Accra, 1929.*

| Date. | 12 mid-night. | 4 a.m. | 8 a.m. | 12 noon. | 4 p.m. | 8 p.m. |
|---|---|---|---|---|---|---|
| 26th Dec., R.H. .. | 91 | 90 | 88 | 52 | 62 | 60 |
| M.% .. | | | 6.5 | 6.1 | 6.0 | |
| 27th Dec., R.H. .. | 44 | 35 | 34 | 50 | 48 | 42 |
| M.% .. | | | 5.1 | 4.9 | 4.6 | |
| 28th Dec., R.H. .. | 37 | 40 | 50 | 33 | 50 | 51 |
| M.% .. | | | 4.3 | 4.2 | 4.0 | |
| 29th Dec., R.H. .. | 45 | 44 | 52 | 42 | 50 | 55 |
| M.% .. | | | 3.9 | | 3.7 | |
| 30th Dec., R.H. .. | 50 | 50 | 48 | 38 | 50 | 48 |
| M.% .. | | | 3.7 | | 3.6 | |
| 31st Dec., R.H. .. | 60 | 78 | 66 | 40 | 58 | 74 |
| M.% .. | | | 3.8 | 3.8 | 3.8 | |
| 1st Jan., R.H. .. | 98 | 99 | 93 | 58 | 67 | 86 |
| M.% | | | 4.9 | | 4.7 | |
| 2nd Jan., R.H. .. | 85 | 96 | 89 | 50 | 72 | 98 |
| M.% .. | | | 5.4 | 5.3 | 5.1 | |
| 3rd Jan., R.H. .. | 96 | 92 | 90 | 72 | 82 | 95 |
| M.% .. | | | 6.5 | 6.3 | 6.0 | |
| 4th Jan., R.H. .. | 92 | 92 | 90 | 68 | 80 | 96 |
| M.% .. | | | 7.3 | 7.2 | 6.7 | |
| 5th Jan., R.H. .. | 92 | 92 | 90 | 75 | 88 | 93 |
| M.% .. | | | 8.0 | 7.8 | 7.7 | |
| 6th Jan., R.H. .. | 91 | 90 | 88 | 70 | 93 | 85 |
| M.% .. | | | 8.8 | | 7.9 | |
| 7th Jan., R.H. .. | 94 | 91 | 90 | | | |
| M.% .. | | | 8.9 | | | |

Plate No. XVII, after the 23rd of December, shows how the cacao beans reacted to the harmattan. Unfortunately the harmattan only lasted for three days and the beans were never allowed to come into equilibrium with it.

It will be observed that after the cessation of the harmattan the relative humidity rose to an average of 86 R.H. (far above that experienced in the cacao store). The cacao beans absorbed moisture to the extent of 8.9% (1.2% more than the equilibrium of the store atmosphere) and had almost reached equilibrium, as the curve in Plate No. XVII will show. The equilibrium

calculated from Plate No. XVI should be 9% moisture for an atmosphere of 86 R.H.

### b. Cacao exposed in open room.

One hundred cacao beans of known moisture content were placed in the gauze sided room behind the Aburi laboratory. They were thus exposed to the atmosphere unprotected except against rain.

After 19 days the experiment was given up because the beans were decomposed by excessive mould formation. No figures are shown because no hygrometer was available and without four hourly readings thereon it is impossible to estimate the dominating atmosphere. A perusal of Plate No. XVIII on which are recorded the daily readings on wet and dry bulb thermometers will show that absorption was approaching its limit at 9.5%. Using Plate No. XVI, one would come to the conclusion that the atmosphere in the above room had an average of approximately 86 R.H. The evening mists were blown into the room by the wind and drops of water were probably precipitated regularly on the surface of the beans. Hence the rapid formation of mould.

### c. Improperly dried beans exposed in Aburi Garden store.

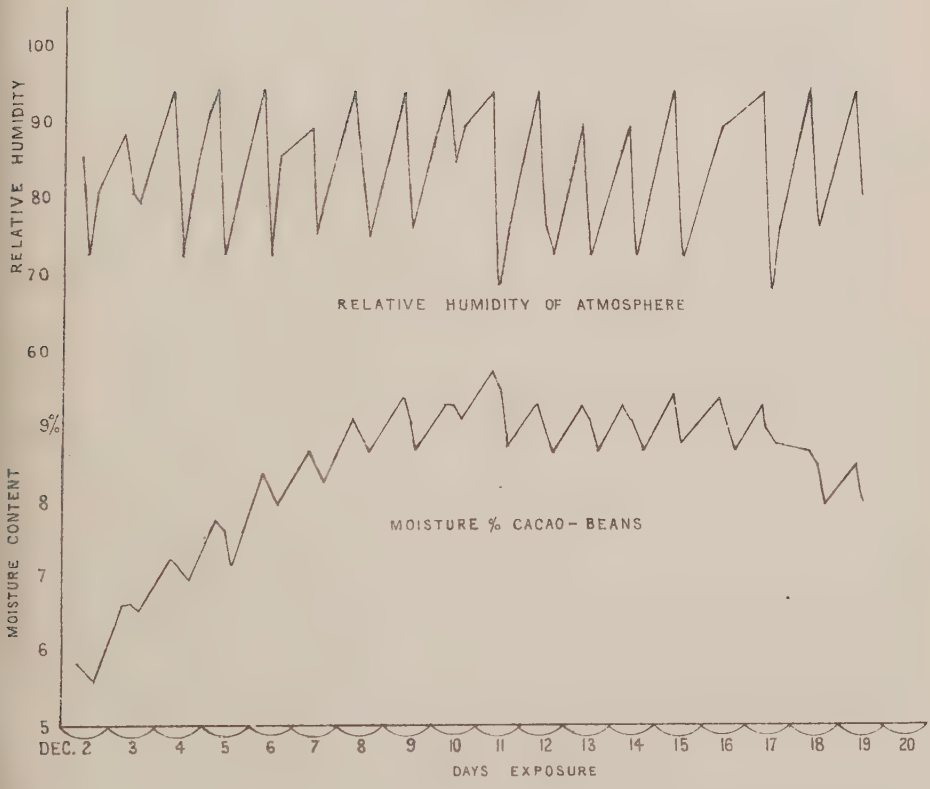
It has already been seen that beans dried to a moisture content below equilibrium with any atmosphere come back to that equilibrium comparatively quickly. It now remains to be seen what is the action of improperly dried beans.

One hundred beans which had been dried to 11.3% moisture were placed in a dish in Aburi cacao store and observed from December 23, 1928, to January 27, 1929. The following table gives the results :—

| Date. | 12 Midnight. | 4 a.m. | 8 a.m. | 12 Noon. | 4 p.m. | 8 p.m. |
|---|---|---|---|---|---|---|
| Dec. 23rd R.H. .. | 92 | 94 | 93 | 62 | 60 | 90 |
| M.%. .. | | | 11.3 | | 10.6 | |
| Dec. 24th R.H. .. | 91 | 92 | 92 | 63 | 63 | 84 |
| M.%. .. | | | 10.7 | 10.3 | 9.9 | |
| Dec. 25th R.H. .. | 90 | 91 | 89 | 58 | 52 | 82 |
| M.%. .. | | | 10.1 | 9.9 | 9.6 | |
| Dec. 26th R.H. .. | 90 | 91 | 86 | 59 | 50 | 66 |
| M.%. .. | | | 9.8 | 9.1 | 8.5 | |

Plate XVIII

CACAO EXPOSED IN GAUZE ROOM
MOISTURE CHANGES COMPARED WITH CHANGES
IN ATMOSPHERIC RELATIVE HUMIDITY.




*Survey H.Q. Accra. 1929.*

| Date. | 12 Midnight. | 4 a.m. | 8 a.m. | 12 Noon. | 4 p.m. | 8 p.m. |
|---|---|---|---|---|---|---|
| Dec. 27th R.H. .. | 54 | 40 | 32 | 39 | 40 | 43 |
| M.%. .. | | | 7.9 | 7.7 | 7.3 | |
| Dec. 28th R.H. .. | 42 | 41 | 46 | 29 | 41 | 50 |
| M.%. .. | | | 6.9 | 6.8 | 6.6 | |
| Dec. 29th R.H. .. | 46 | 42 | 45 | 37 | 41 | 52 |
| M.%. .. | | | 6.4 | | 6.1 | |
| Dec. 30th R.H. .. | 56 | 57 | 50 | 35 | 42 | 57 |
| M.%. .. | | | 6.0 | | 5.7 | |
| Dec. 31st R.H. .. | 60 | 70 | 64 | 63 | 70 | 88 |
| M.%. .. | | | 5.7 | 5.7 | 5.5 | |
| Jan. 1st R.H. .. | 91 | 92 | 93 | 67 | 70 | 84 |
| M.%. .. | | | 6.0 | | 5.4 | |
| Jan. 2nd R.H. .. | 87 | 94 | 95 | 73 | 76 | 86 |
| M.%. .. | | | 6.2 | 6.1 | 5.9 | |
| Jan. 3rd R.H. .. | 90 | 95 | 92 | 66 | 66 | 85 |
| M.%. .. | | | 6.6 | 6.4 | 6.2 | |
| Jan. 4th R.H. .. | 93 | 93 | 90 | 61 | 75 | 85 |
| M.%. .. | | | 6.9 | 6.8 | 6.2 | |
| Jan. 5th R.H. .. | 94 | 92 | 96 | 58 | 66 | 87 |
| M.%. .. | | | 7.2 | 7.1 | 6.9 | |
| Jan. 6th R.H. .. | 92 | 94 | 93 | 62 | 60 | 90 |
| M.%. .. | | | 7.6 | | 6.8 | |
| Jan. 7th R.H. .. | 91 | 92 | 92 | | | |
| M.%. .. | | | 7.4 | 7.2 | 6.8 | |
| Jan. 8th R.H. .. | 92 | 93 | 93 | 65 | 75 | 90 |
| M.%. .. | | | 7.5 | | 6.9 | |
| Jan. 9th R.H. .. | 93 | 95 | 94 | 63 | 70 | 85 |
| M.%. .. | | | 7.8 | | 7.1 | |
| Jan. 10th R.H. .. | 94 | 94 | 91 | 66 | 76 | 90 |
| M.%. .. | | | 7.6 | 7.5 | 7.1 | |
| Jan. 11th R.H. .. | 94 | 95 | 93 | 70 | 72 | 90 |
| M.%. .. | | | 7.8 | 7.2 | 7.5 | |
| Jan. 12th R.H. .. | 92 | 93 | 94 | 60 | 56 | 18 |
| M.%. .. | | | 8.0 | 7.0 | | |

It will be observed that from January 1st to January 12th the atmosphere did not have a general change. By taking the average of the four-hourly readings on the hygrometer during that period an atmosphere of 83 is obtained. Using Plate No. XVI it will be seen that cacao should contain 8.2% of moisture in such an atmosphere. On the 12th of January the cacao in this experiment had reached a maximum of 8% and had not stopped gaining weight. This is another proof that the average R.H. as obtained in this paper gives a good description of the dominating atmosphere.

Plate No. XIX gives the curve for the above table. A false impression of the rate at which wet cacao loses moisture is given in this experiment because of the very severe harmattan which came on the 27th of December. The fact remains however that cacao loses moisture just as quickly as it gains moisture according to the negative or positive position of its moisture content to the equilibrium point of the atmosphere in which it is placed. Again, the daily fluctuations in R.H. merely act as breaks.

## VI. THE PRACTICAL SIDE OF RESULTS OBTAINED IN THESE EXPERIMENTS.

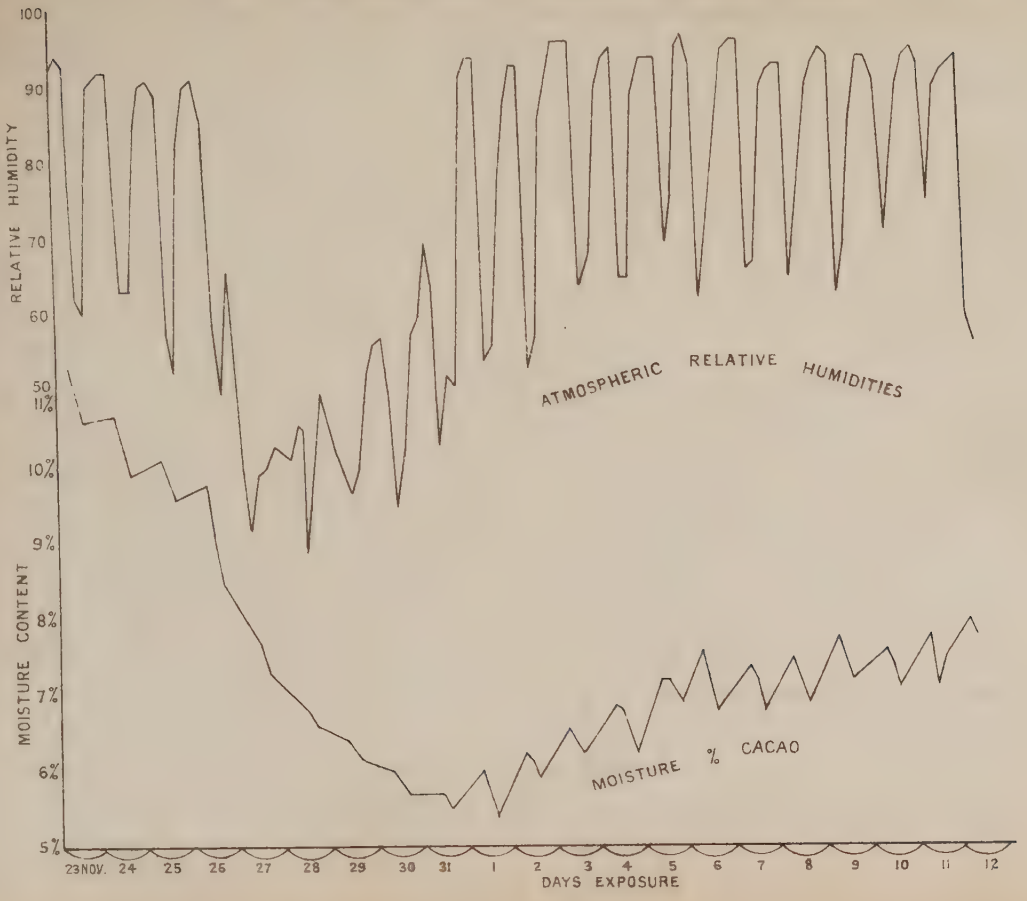
It has now been demonstrated that well dried cacao exposed to the atmosphere of an ordinary store will increase in moisture content until it comes to equilibrium with that atmosphere. The daily variations are not really important except as variates in a series of R.Hs. whose average is the dominating atmosphere.

This means that one would expect cacao stored in a wet place like Aburi to have a higher moisture content than cacao stored in Accra. If the atmosphere is very wet, as it is at Aburi during the wet season, it is possible that the beans will absorb enough moisture to form mould.

A distinct change in the general atmospheric conditions will affect the beans almost immediately and, although the attainment of absolute equilibrium will take possibly a fortnight, the approach to within less than 1% of the ultimate moisture content can be accomplished within a day or two. That is to say that, if it rained steadily for a week, and the R.H. had an average of anything above 86 per cent beans stored in an ordinary store without bags would probably have a moisture content of more than 9%. This is an important fact. The effect of protecting these beans by means of bags has yet to be determined.

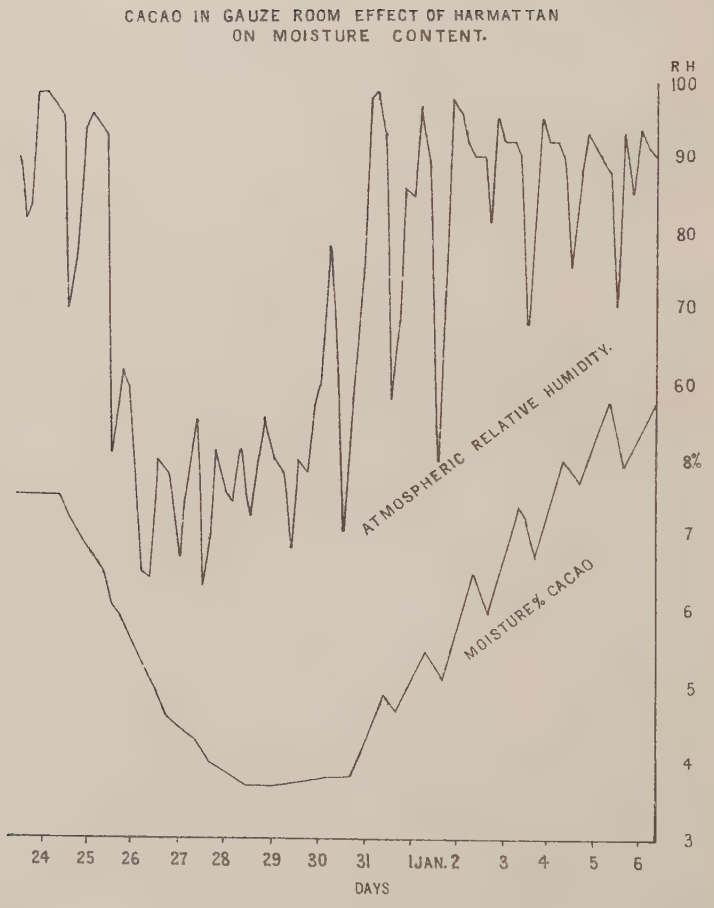
These experiments lead the way to further investigation as to the result of storing cacao. They point to the fact that cacao must be protected against the atmosphere in wet parts of the Colony. They prove that the question of good storing is just as important a factor as proper drying. A detailed examination of the amount

CACAO IN STORE (ABURI) EFFECT OF HARMATTAN ON MOISTURE CONTENT.




Survey H.Q. Accra, 1929.

Plate XX




*Survey H. Q. Accra, 1929.*

of protection afforded by a bag has yet to be made. To what extent it influences the rise in moisture content of the bean itself will be the object of future investigation.

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The question of moisture content in cacao beans is one which is naturally very closely associated with moulds, and has engaged the attention of the mycological division for a considerable period of time. Mr. H. A. Dade has collected a great deal of information on the subject and the writer of this article takes this opportunity of thanking him for his courtesy in supplying material and advice which acted as very useful guides in these experiments.

PAPER No. X.

# INTERNAL MOULDING OF PREPARED CACAO.

By H. A. DADE.

The occurrence of moulds in prepared cacao is regarded by merchants and manufacturers as a serious defect. The government of one of the largest consuming countries, the United States, refuses to allow importation of cacao containing more than 10% of mouldy beans or 15% mouldy and weevilly beans. The Liverpool Chamber of Commerce standard for Gold Coast cacao is 10% "slatey" and 10% "defective." Premiums are offered for better qualities, but cacao containing more than 10% defective is not tenderable.

Of the defects other than slate, mould is perhaps the most important.

Internal moulding does not appear to occur to a sufficient extent to constitute a serious defect in the cacao exported from other major producing countries. It would appear therefore that West African conditions are particularly favourable for its incidence, and it will be seen that this is so.

Investigation—with the object of discovering means of preventing moulding—falls into five definite groups :—

(1) The conditions under which moulding can occur.

(2) The circumstances and stages in the history of the product in which conditions permitting moulding occur.

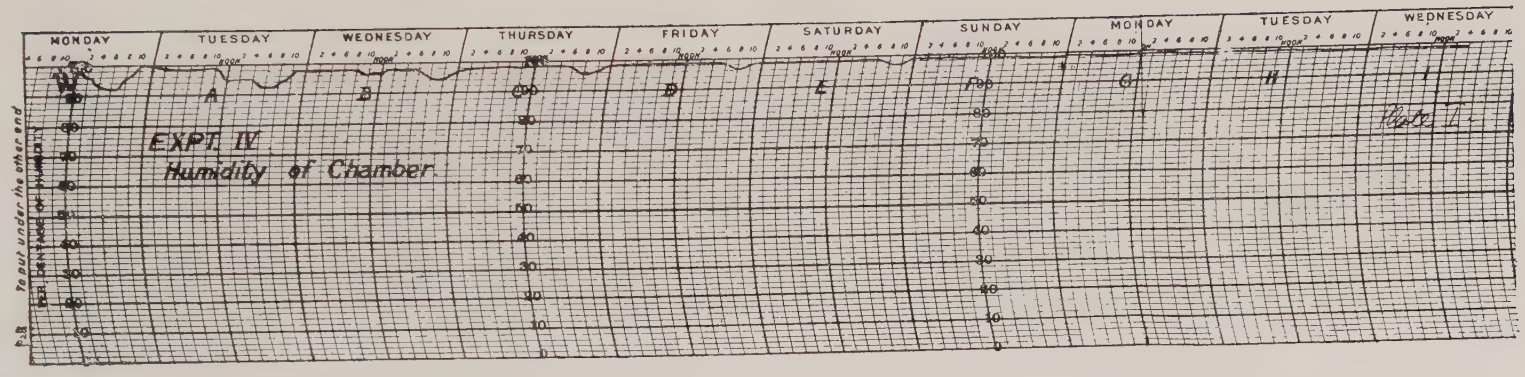
(3) The means by which the cacao becomes infected internally by the mould fungi.

(4) The stage in which infection occurs.

(5) The identity and properties of the responsible fungi.

Several Divisions of the Department of Agriculture have made relevant investigations which will be found in other articles in this Year Book. In Paper No. VIII Bunting describes the organisms responsible for moulding, and in Paper No. IX Scott describes the relation between the water content of cacao and atmospheric humidity.

PLATE XXI.


MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
NOON
A
B
C
D
E
F
G
H
I
EXPT. IV.
Humidity of Chamber.
Plate I.
To put under the other end
PER CENTAGE OF HUMIDITY

## I. CONDITIONS UNDER WHICH MOULDING CAN OCCUR.

Damage by moulds to products of organic origin is of common occurrence and has been widely studied. In general terms, favourable conditions for the incidence of mould fungi are—(*a*) existence of nutritive substratum, (*b*) suitable temperature, (*c*) adequate water supply.

In cacao numerous fungi find suitable food material not only in the cell contents of the embryo but also in the material left by the evaporation of the juices which are found inside the freshly fermented bean. Laboratory experiments have shown that the latter material alone is sufficient to support a growth of mould which will render the bean, in the commercial sense, " mouldy." (Mould, from the commercial point of view, means mycelium and fungus fructifications which are visible to the naked eye.*) It must be understood that the mere presence of a fungus in quantity is enough, according to the manufacturers, to give an undesirable flavour to the manufactured chocolate or cocoa, and that actual damage to the embryo does not necessarily—in fact seldom if ever does in ordinary commercial practice—occur. The United States import regulations are based on the assumption that the presence of mould on raw cacao has a harmful effect on the consumer of the manufactured chocolate or cocoa.

The temperature to which cacao is subjected during its passage from the producer to the port of entry is, throughout all but possibly the last stage of the sea voyage, very favourable indeed for the fungi with which we are concerned, ranging from about 25°C. to 54°C in the fermentation heap, and from 25°C. to about 35°C. or more in storage. No information as to the temperature of ships' holds is available at present, but in tropical and sub-tropical latitudes they are undoubtedly favourable, and may very well be even in higher latitudes.

Two fungi concerned in moulding thrive in fermentation heaps, but grow less rapidly at air temperature. The others, while they survive in the temperature of fermentation mass, do not grow there, but find their optimum growth temperature within the range of air temperature which is normal in West Africa.

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*The term " commercially mouldy " will be found frequently in this paper. It is used to describe cacao which would be called mouldy by merchants, as distinct from cacao in which internal moulds are present, but not perceptible to the naked eye. The latter is not important commercially at the time of sampling, but is potentially important if conditions permit further growth. Such cacao forms a part of every batch in which commercial mould exists.

As all cacao merchants are aware by experience, the water content of the product is of first importance, as it is in the cases of many other plant products which are liable to moulding. They know very well that insufficiently dried cacao becomes mouldy. Buyers in West Africa have their own rule of thumb methods of determining whether their purchase has been well dried. It seems however very probable that the rough tests applied are not altogether accurate—that is, sufficiently accurate. They have certainly not been put to thorough scientific proof. Two batches of cacao recently prepared by an experienced overseer afford an example. Both passed all the usual tests, but water content determinations showed that they contained 4.7% and 9.0% of water respectively. The former was, as we shall see, really thoroughly dried from the point of view of moulding, in fact was so dry that the "shells" (testæ) were undesirably brittle. The latter batch fell below the standard of dryness proposed in this paper.

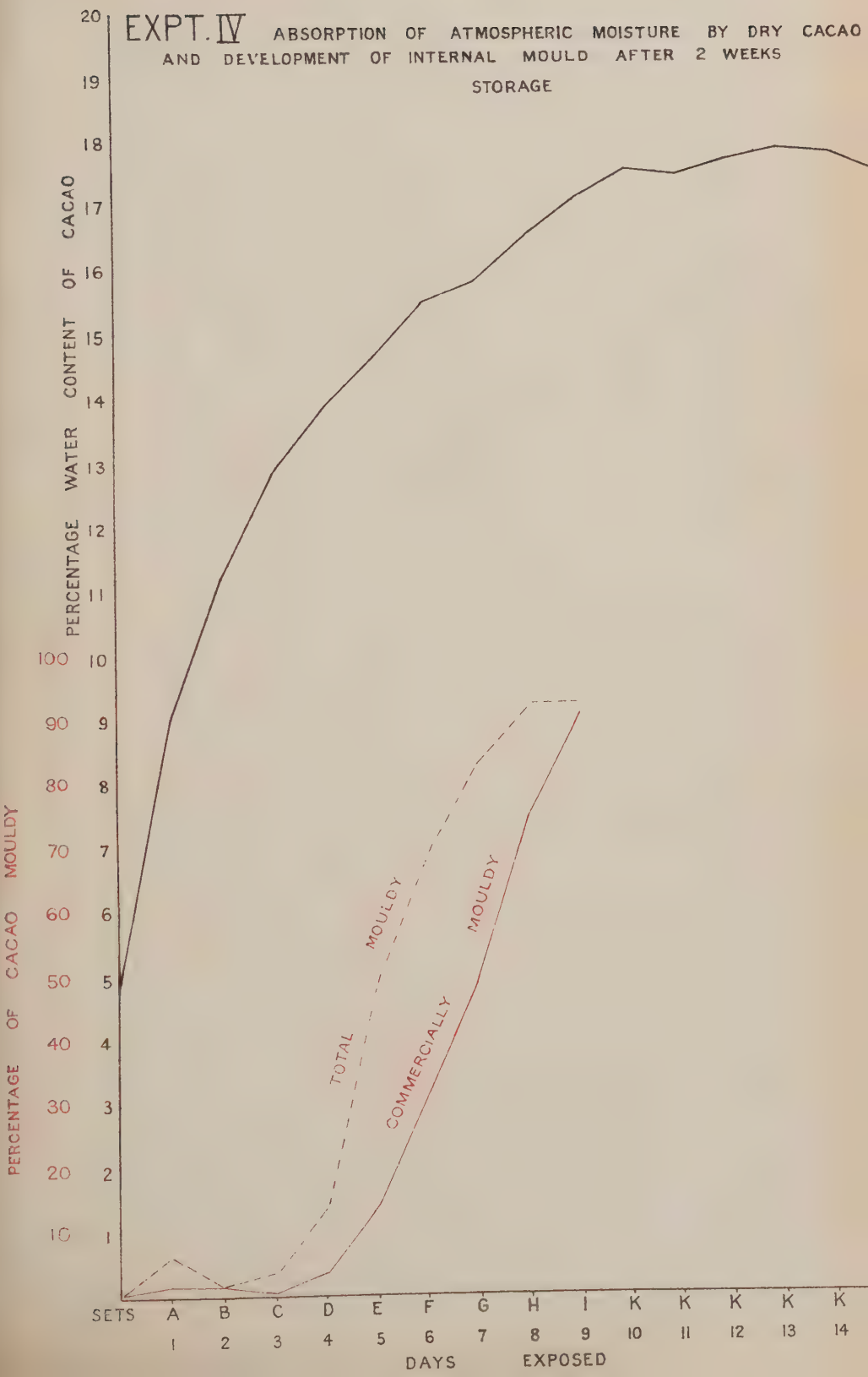
It is obvious—and merchants know by experience—that cacao dried below the limit of water content necessary to support mould growth, and *retained* below that limit, does not develop internal mould. Before we can proceed any further we must know what that limit may be.

A series of experiments to determine the limit have been carried out. As the basis of experimental method the systems of using (1) freshly fermented cacao removed from drying mats at intervals during the drying process; (2) initially thoroughly dried cacao and raising its water content to different points by exposure to a saturated atmosphere, are convenient.

**(a) Experiments by absorption of atmospheric moisture.**

Preliminary experiments by this method were carried out by placing lots of cacao in the usual form of chemical desiccator, the lower part of which was filled with water. This proved to be unsatisfactory owing to the variation in degree of saturation brought about by fluctuations of temperature, and for other practical reasons. In subsequent experiments therefore a portable culture chamber was converted into a moist chamber. This chamber was provided with hand-holes and an observation port on one side, which facilitated manipulation of the contents without occasioning any appreciable change in the condition of the internal atmosphere. The chamber, which was open at the bottom, was sealed with plasticine to a slate slab. Shallow dishes filled with water occupied the complete area of the bottom of the chamber, and above these were fixed wire frames fitted with horizontal glass rods on which trays of cacao were supported.

An Edney Hair Hygrometer was also put into the chamber and records of the humidity thus obtained. Wet towels, with their lower ends dipping into the dishes of water were suspended


EXPT. IV ABSORPTION OF ATMOSPHERIC MOISTURE BY DRY CACAO AND DEVELOPMENT OF INTERNAL MOULD AFTER 2 WEEKS STORAGE
PERCENTAGE WATER CONTENT OF CACAO
PERCENTAGE OF CACAO MOULDY
TOTAL MOULDY
COMMERCIALLY MOULDY
SETS A B C D E F G H I K K K K K
1 2 3 4 5 6 7 8 9 10 11 12 13 14
DAYS EXPOSED

from the inner walls of the chamber and provided a large surface for evaporation. The chamber was covered externally with several layers of towels which served as insulation, and the whole apparatus was placed in the part of the laboratory most free from fluctuations of temperature.

A very steady relative humidity was maintained inside the chamber, the maximum range of fluctuation occurring during the first day of the experiments. (*See* reproductions of record. Plate XXI). The daily fluctuation became less as the considerable mass of cacao reached equilibrium with the internal atmosphere.

Batches of 2,000 beans were used. These were divided into ten sets, A to K, each of 200 beans, and each set was sub-divided into ten lots of 20 beans. The lots of 20 beans were placed in small paper trays, which were arranged on the glass rod supports in Latin squares, in order to compensate for any slight differences in saturation which might exist in different parts of the chamber.

*Experiment IV* was designed to indicate the minimum percentage water content at which moulding may occur.

The ten sets A–K were removed through the hand-holes after one to ten days exposure respectively. The water content of the batch was determined and the sets were weighed previous to exposure. The sets were weighed again immediately after withdrawal from the chamber and their final water content thus calculated.

After removal and weighing the sets were stored in stoppered jars in order that the water content might be kept practically constant. After two weeks storage the sets were cut and examined first with the naked eye and then with a X 10 binocular magnifier.

Results are shown in the graph in Plate XXII and in Table I. Set K was not stored in this experiment, but after weighing was returned to the chamber and again withdrawn and weighed for five more days. This set indicated that saturation of this batch of cacao was reached at about 18% water content. Reference to the mould curve shows that commercial moulding began (during two weeks storage) at between 13 and 14 per cent. water content.

The curve marked " total mouldy " includes cases of mould visible with a X 10 lens in addition to " commercially mouldy " cases

In the earlier sets the moulds had not sporulated and it was not possible to definitely identify the mycelium. In Sets E to I most of the moulds which occurred were identified—*see* Table I.

The predominance of *Aspergillus glaucus* is significant.

## TABLE I.

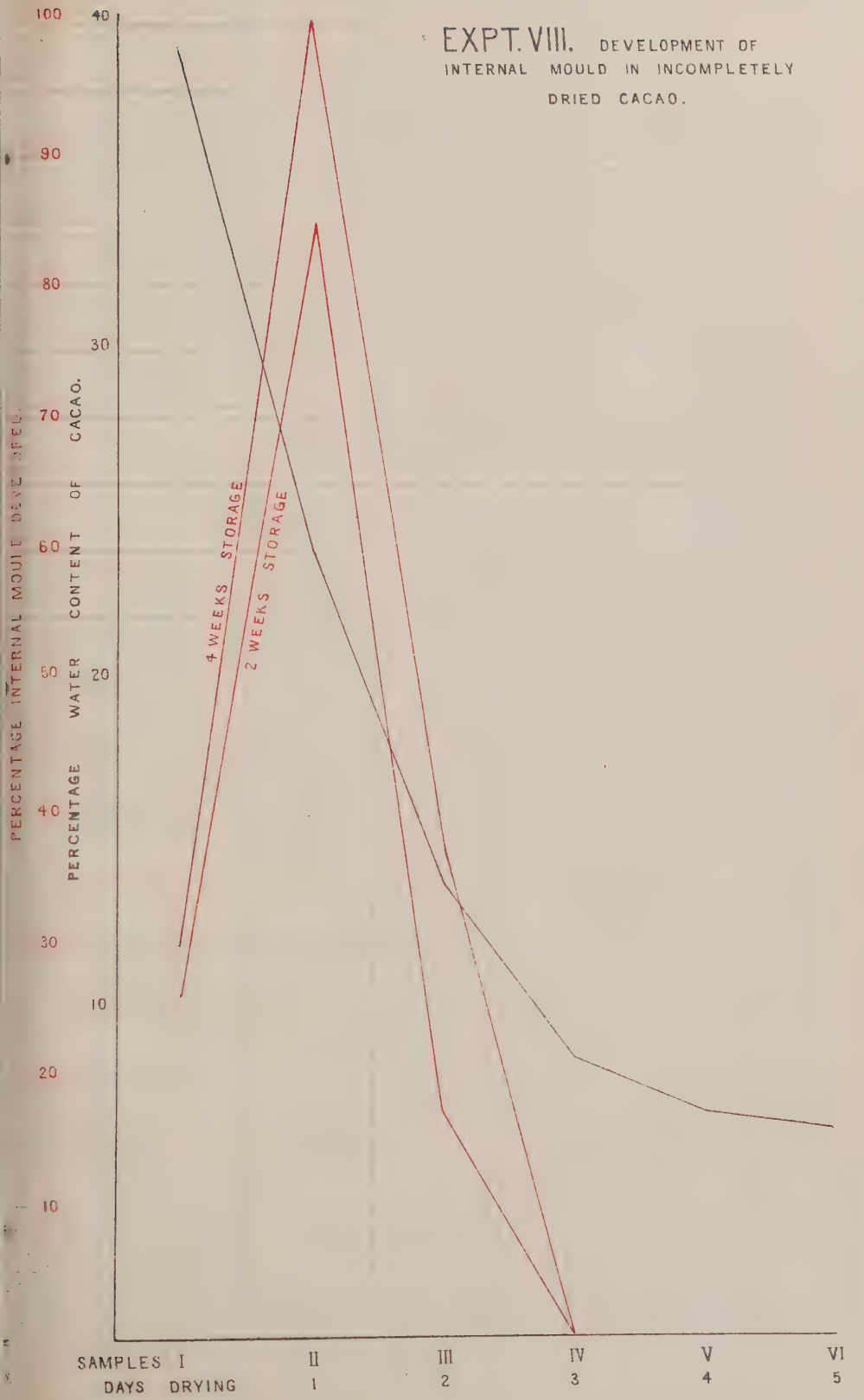
### Incidence of Internal Mould, Experiment IV.

| Set. | Commercial Mould. | | | | | | | | Trace of mould per cent. | Total mould per cent. | Water content of Sets per cent. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. glaucus. | A. fumigatus. | Penicillium sp. | A. glaucus and Penicillium sp. | A. flavus. | A. fumigatus and A. glaucus. | Undetermined. | Total per cent. | | | |
| A | | | | | | | 1 | 1 | 5 | 6 | 9.1 |
| B | | | | | | | 1 | 1 | 1 | 2 | 11.2 |
| C | | | | | | | 0 | 0 | 3 | 3 | 12.8 |
| D | | | | | | | 3 | 3 | 10 | 13 | 13.9 |
| E | 7 | 1 | 1 | — | — | — | 4 | 13 | 35 | 48 | 14.6 |
| F | 19 | 2 | — | — | — | — | 9 | 30 | 38 | 68 | 15.5 |
| G | 45 | 1 | 1 | — | — | — | 2 | 49 | 33 | 82 | 15.8 |
| H | 57 | 6 | 3 | 1 | — | — | 8 | 75 | 16 | 91 | 16.5 |
| I | 69 | 5 | — | — | 1 | 1 | 17 | 90 | 2 | 92 | 17.1 |
| F′ | 23 | 5 | — | — | — | — | 3 | 32 | 43 | 75 | 15.5 |
| H′ | .. | See | below | .. | .. | .. | .. | 100 | — | 100 | 16.5 |

## TABLE II.

### Analysis of Moulds in Set H′.

| | |
|---|---|
| A. glaucus .. .. .. .. .. .. .. .. .. .. | 1 |
| A. flavus .. .. .. .. .. .. .. .. .. .. | 3 |
| A. ochraceus .. .. .. .. .. .. .. .. .. .. | 2 |
| A. tamari .. .. .. .. .. .. .. .. .. .. | 4 |
| Penicillium sp. .. .. .. .. .. .. .. .. .. | 33 |
| A. glaucus + Penicillium sp. .. .. .. .. .. .. | 13 |
| A. glaucus + Penicillium sp. + A. tamari .. .. .. .. .. | 6 |
| A. ochraceus + A. tamari .. .. .. .. .. .. .. .. | 1 |
| A. fumigatus + A. tamari .. .. .. .. .. .. .. .. | 2 |
| A. glaucus + Pencillium sp. + Mucor sp. 463 .. .. .. .. | 1 |
| A. flavus + A. tamari + Penicillium sp. .. .. .. .. .. | 1 |
| A. flavus + Penicillium sp. .. .. .. .. .. .. .. | 1 |
| A. tamari + Penicillium sp. .. .. .. .. .. .. .. | 16 |
| A. ochraceus + Penicillium sp. .. .. .. .. .. .. .. | 6 |
| A. glaucus + undet. .. .. .. .. .. .. .. .. | 1 |
| A. tamari + undet. .. .. .. .. .. .. .. .. | 1 |
| Penicillium sp. + undet. .. .. .. .. .. .. .. .. | 1 |
| Undet. .. .. .. .. .. .. .. .. .. .. | 7 |
| | 100 |




Survey H.Q. Accra, 1929.

In two respects this experiment gave dissatisfaction. The period of storage was probably not sufficiently prolonged. The sets after withdrawal were stored in closed jars, and the accumulation of carbon dioxide in the jars probably inhibited growth. A duplicate set of F (F′) was available and was stored for six weeks, but showed no appreciable increase of mould in that time. A duplicate of H (H′) was kept in a jar which cracked during storage, and in this set, when it was examined after six weeks storage, 100 per cent. of mould was found, all but two of the fungi concerned in moulding being present—*see* Table II.

Improved storage methods had therefore to be adopted in subsequent experiments.

In Experiment IV. *A. glaucus* is the first mould to appear in the stored cacao, a fact which was also evident from the examination of many commercial samples of cacao.

The probable reasons for this are discussed later. Although carbon dioxide accumulated in the storage jars, the sets showed an increase in mould corresponding with the water content. Much growth thus occurred in the jars before the increasing carbon dioxide checked it, and subsequent work showed that internal infection had already begun while the sets were still in the moist chamber—see Experiment XI.

*Experiment XIV.* was a repetition of Experiment IV. in which storage was continued for eight weeks. The sets were stored in cylindrical glass jars which were stacked horizontally with slightly loosened lids, to permit the escape of carbon dioxide and at the same time to prevent any considerable change in water content by evaporation. Results are shown in Table III.

TABLE III.

| Set. | Water content per cent. | Internal moulds per cent after storage for— | | External moulds. |
|---|---|---|---|---|
| | | 4 weeks. | 8 weeks. | |
| 1 | 9.5 | Nil | 7.4 | A. glaucus. |
| 2 | 10.2 | „ | 8.5 | „ „ |
| 3 | 10.8 | 10.5 | 16 | profuse sporulation and formation of perithecia. |
| 4 | 11.2 | 26 | 29.5 | |
| 5 | 13 | 69 | 95 | |

It is therefore apparent that 9.5 per cent. water content is sufficient to permit moulding within two months. The presence, on the outside of the beans, of *A. glaucus* is a definite indication of the final appearance of internal mould, though it may be slow to appear in the drier samples.

### (b) Experiments in incomplete drying.

*Experiment VIII.* A freshly fermented batch of cacao was set out to dry on mats in the usual manner. Each day samples of 200 beans each were taken from the mats and stored in jars as in Experiment XIV above.

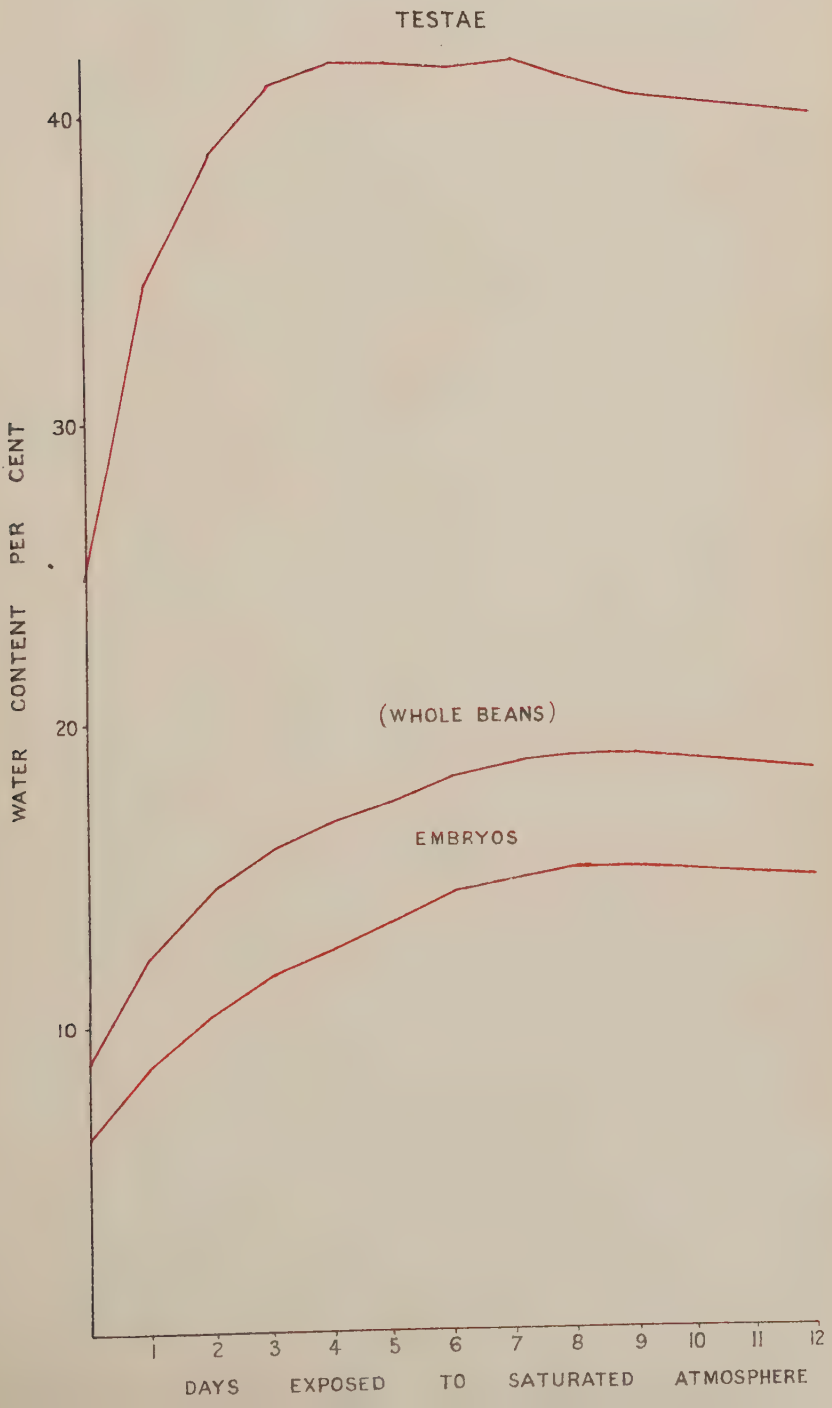
The samples were each divided into two lots of 100 beans. which were cut and examined after two and four weeks respectively, The results are shown graphically in Plate XXIII, and in Table IV.

After four weeks 37% of mould was found in the sample containing 13.8 per cent. of water, and none in that containing 8.4 per cent. of water.

There are some points of considerable interest demonstrated by this experiment. One remarkable fact is the comparatively low incidence of moulding in the first sample, which was taken after the cacao had been exposed on drying mats for about three hours. This sample contained 38.9 per cent. of water and 26 per cent. and 30 per cent. of mould occurred after two and four weeks respectively. Sample II contained 23.5 per cent. of water and 85 per cent. and 100 per cent internal moulding occurred after two and four weeks respectively. Evidently mould growth was inhibited in the wetter set. Wet beans freshly removed from the fermentation mass contain a considerable quantity of alcohol, and if they are stored immediately in sealed jars they remain in perfect condition for years. Alcohol was possibly the inhibiting agent in the case of sample I. Bacteria however were present in large numbers.

The difference in the fungus flora of the three mouldy samples is very distinct. While *A. flavus* and *A. tamari* were predominant in the wetter samples, *A. glaucus* was the only significant fungus in the drier sample. Evidently a water content of 13.8 per cent. is too low for the successful growth of moulds other than *A. glaucus*.

# EXPT. X. ABSORPTION OF ATMOSPHERIC MOISTURE BY SEPARATED TESTAE AND EMBRYOS OF CACAO.



## TABLE IV.

### Incidence of Internal Mould in Experiment VIII.

| Sample. | Water content % | External moulds. | Internal Moulds (Commercial) | | | | Remarks. |
|---|---|---|---|---|---|---|---|
| | | | After 2 weeks. | | After 4 weeks. | | |
| | | | % | | % | | |
| I. | 38.9 | *A. tamari*, *A. flavus*, Yeasts. (Possibly Actinomyces). | 26 | *A. tamari*, *A. flavus*, *Absidia regneri* (1). | 30 | *A. tamari*, *A. flavus*, *Absidia regneri* (1). | Non-mouldy beans pale sickly brown to yellow. All slightly acid except those reduced to bacterial mush, which were neutral. |
| II. | 23.5 | *A. tamari*, *A. flavus*, *Absidia capillata*, A little *A. glaucus* and *A. niger*. | 85 | *A. tamari*, *A. flavus*, *Absidia regneri*, *A. fumigatus* (1). | 100 | *A. tamari*, *A. flavus*, *Absidia regneri*, *A. flavus* (with sclerotia). | *A. tamari*, *A. flavus*, predominating *Absidia regneri* only other significant fungus. |
| III. | 13.8 | *A. glaucus*, (conidia & perithecia.) Trace of *Absidia capillata* & white Aspergillus. | 17 | *A. glaucus*, *Absidia regneri* (1). | 37 | *A. glaucus*, *Penicillium sp.* (1). | *A. glaucus* preponderating. No other significant fungus. |
| IV. | 8.4 | Nil | Nil | Nil | Nil | Nil | Too dry to permit moulding. |
| V. | 6.8 | Nil | Nil | Nil | Nil | Nil | |
| VI. | 6.2 | Nil | Nil | Nil | Nil | Nil | |

*Experiment XII.* This was a repetition of Experiment VIII with some difference of method.

From a freshly fermented batch of cacao ten lots of 500 beans were taken, weighed, and set out to dry. The water content of the

wet cacao was found from a further sample, and from that were calculated the final weights of the ten samples corresponding with water contents of 6 to 15 per cent. with intervals of one per cent.

(For practical commercial purposes it is unnecessary to determine the critical degree of dryness with greater accuracy than one per cent. and in the case of cacao, where it is not possible to control perfectly the processes of fermentation and drying, the product is necessarily heterogeneous and it is not possible to obtain reliable results with very great accuracy).

The ten lots were weighed frequently during drying, and when they had reached the weights estimated to correspond with the required dryness they were stored in inverted flasks, the necks of which were plugged with wire gauze at the bulge, and with slotted corks at the mouth. The removal of carbon dioxide was thus ensured, and evaporation reduced as far as possible.

A sample from each lot was taken at the time of storing, and the actual water content determined.

Results are shown in Table V.

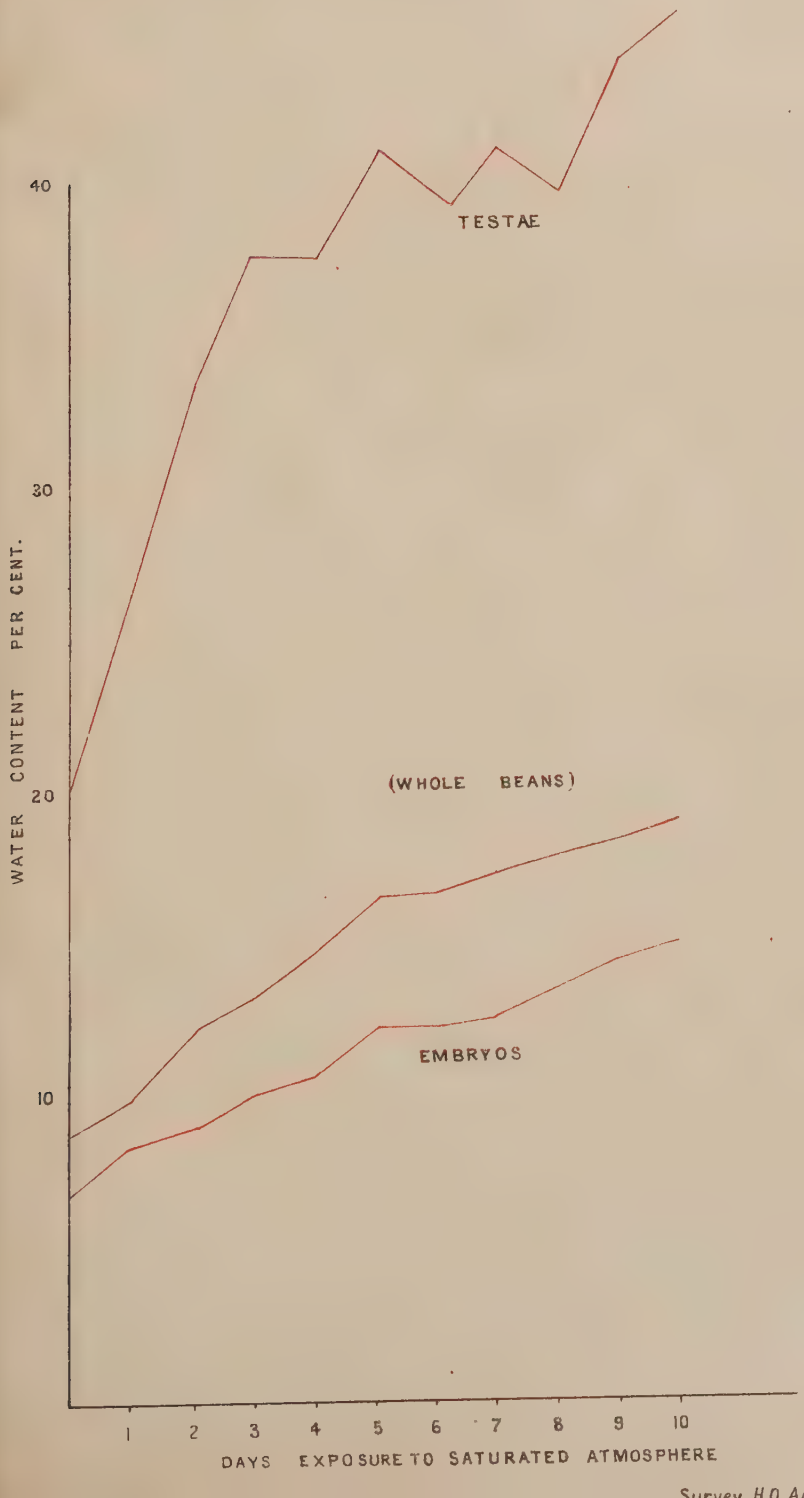
TABLE V.

| Set. | Water content per cent. | Internal moulds after 7 weeks per cent. | Internal moulds after 11 weeks per cent. | External moulds. |
|---|---|---|---|---|
| 1 | 16.4 | 20 | 40 | *A. glaucus.* |
| 2 | 14.8 | 5.5 | 14 | *A. fumigatus.* |
| 3 | 15.2 | 5 | 15 | *Penicillium sp.* |
| 4 | 11.1 | 0 | 10 | |
| 5 | 11.8 | 0 | 3.9 | *A. glaucus.* |
| 6 | 11.5 | 0 | 1.2 | |
| 7 | 10.5 | 0 | 1.35 | |
| 8 | 7.4 | 0 | 0 | |
| 9 | 7.9 | 0 | 0 | |
| 10 | 5.4 | 0 | 0 | |

External moulds appeared slowly. After two weeks Sets 1–3 were mouldy, but six weeks elapsed before mould appeared on Set 7, and this spread slowly.

The method of storage appears to have prevented the ready escape of acetic acid, the odour of which was evident at the mouths of the flasks for a considerable period. This may have inhibited growth.

# EXPT. XI. RELATIVE ABSORPTION OF ATMOSPHERIC MOISTURE BY TESTAE AND EMBRYOS IN WHOLE BEANS




Survey H.Q. Accra, 1929.

*Experiment XIIIB.*

This was a repetition of Experiment VIII in an attempt to obtain shorter brackets by taking samples at shorter intervals.

The results after three and six weeks storage are shown in Table VI.

TABLE VI.

| Set. | Water content per cent. | Internal moulds after storage per cent. for— | | External moulds. |
|---|---|---|---|---|
| | | 3 weeks. | 6 weeks. | |
| 4 | 27 | 100 | 100 | *A. tamari, A. flavus.* |
| 5 | 24 | 100 | 100 | *A. ochraceus, A. glaucus.* |
| 6 | 20 | 99 | 100 | |
| 8 | 16.6 | 38.6 | 100 | |
| 9 | 13.8 | 6 | 27 | |
| 10 | 11.6 | 0 | 18 | *A. glaucus.* |
| 11 | 11.1 | 0 | 0 | |
| 13 | 6.8 | 0 | 0 | |
| 14 | 7.8 | 0 | 0 | |
| 15 | 7.0 | 0 | 0 | Nil. |
| 16 | 7.8 | 0 | 0 | |

In this experiment the appearance of internal mould in Set 11 is only a matter of time.

A number of large samples of cacao were kept in the laboratory for several months at various water contents ranging between five and eight per cent. Mould did not appear in any of these samples, either internally or externally. It is therefore obvious that eight per cent. water content represents a safe degree of dryness.

### (c) Relative loss and absorption of water by testa and embryo.

In interpreting and comparing the results of experiments conducted by the methods of re-absorption of atmospheric moisture and incomplete drying an appreciation of the difference in the physical state of the cacao in these two processes is important. These differences are directly comparable to those which occur in certain stages in the preparation and handling of commercial cacao when moulding may occur (*see* section IV).

The experiments which will now be described were designed to show what are the water contents of the testa and embryo individually in different stages of drying and absorption and to what values of water content of the whole bean they correspond

*Experiment X.* In this experiment the water contents of the whole beans, testæ and embryos of a batch of dry cacao were determined. About 100 grams of the cacao were taken and the testæ removed from the embryos. The testæ and embryos were then weighed separately and exposed to a nearly saturated atmosphere, and were withdrawn and re-weighed daily.

Plate XXIV shows the result graphically.

Starting from a water content of 25 per cent. the testæ reached equilibrium at 42 per cent. water content after four days exposure.

The water content of the embryos rose from 6.6 per cent. to equilibrium at 15.1 per cent. after 7–8 days exposure. (Taken together, as representing the whole beans, water content of which was 8.9 per cent. at the start, equilibrium was reached at 18.9 per cent. after seven days exposure).

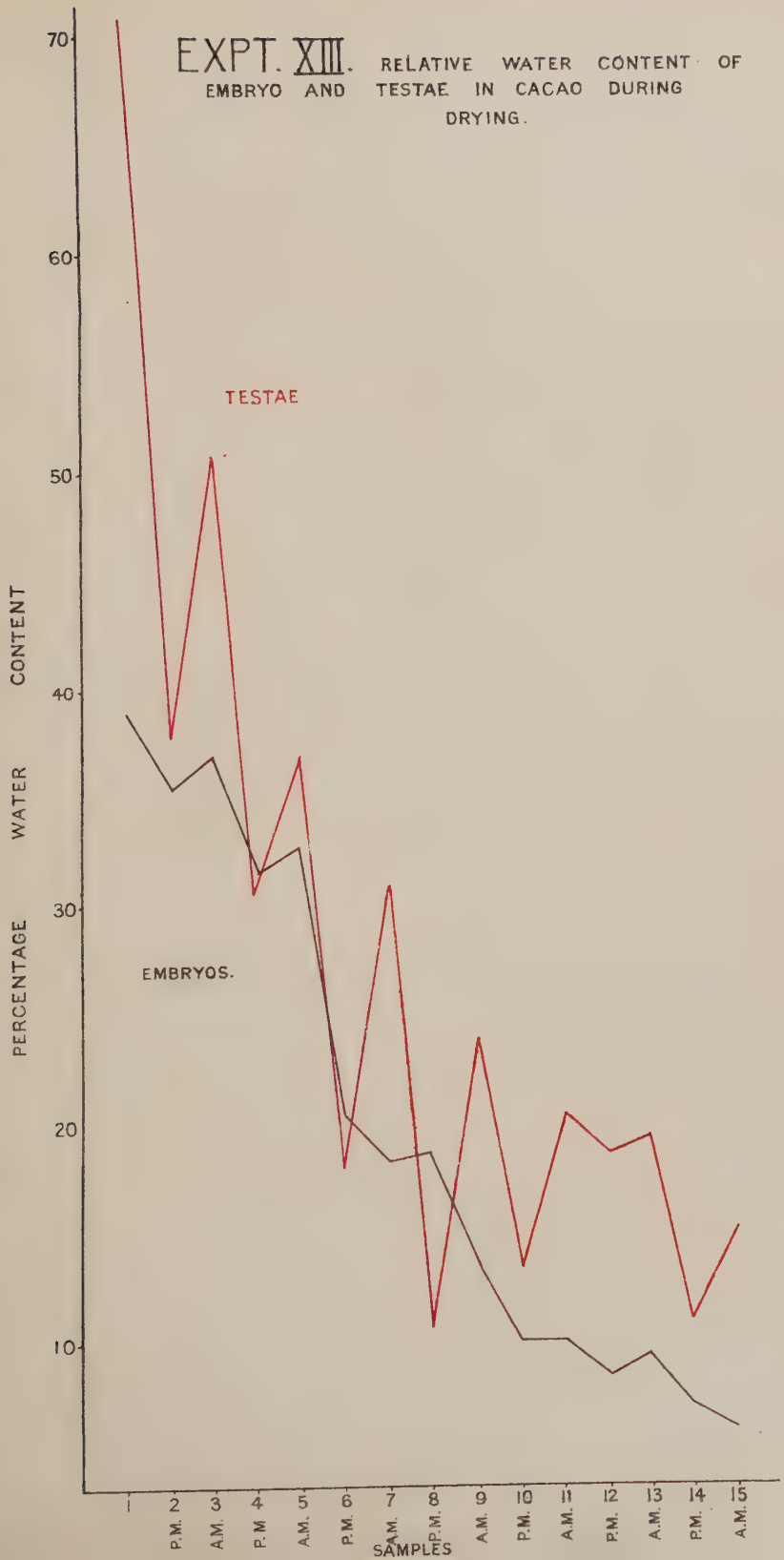
*Experiment XI.* The conditions of exposure in Experiment X are not the same as in the case of whole beans, in which only the outside of the testæ is in contact with the atmosphere. To demonstrate what occurs in the case of whole beans, an absorption experiment was carried out using the same method as in Experiment IV excepting that after weighing, the testæ were quickly removed from the beans, and the embryos re-weighed. The water content of the embryos was determined, and the water contents of the testæ and of the whole beans calculated from the other data.

With this method, some form of which appears to be the only possible one, very accurate results cannot be obtained, owing to the evaporation which takes place during the removal of the testæ. However the results obtained, which are illustrated on Plate XXV indicate with sufficient clearness that there is no significant difference between the absorption phenomena in this and in Experiment X.

In this experiment external moulds were visible on the 5th day (Set E) and *A. glaucus* was found inside the testa in Set F. In G and succeeding sets perithecia were in course of formation inside the bean.

*Experiment XIIIA.* From a batch of drying cacao samples were taken (*a*) at the end of each day's drying (*b*) each morning before the cacao was put out to dry. Parts of the samples were separated into testæ and embryos, and the water content of each determined. The result is shown in Plate XXVI.

It will be seen that the water content of the testa is much lower at the end of a day's drying than it is the following morning. This, towards the end of drying, may be due to the water content of the testæ reaching equilibrium with that of the high nightly humidity, but at other stages it cannot be so because the testa, and the whole bean, is already at a water content above this


EXPT. XIII. RELATIVE WATER CONTENT OF EMBRYO AND TESTAE IN CACAO DURING DRYING.
PERCENTAGE WATER CONTENT
70
60
50
40
30
20
10
TESTAE
EMBRYOS.
1
2 P.M.
3 A.M.
4 P.M.
5 A.M.
6 P.M.
7 A.M.
8 P.M.
9 A.M.
10 P.M.
11 A.M.
12 P.M.
13 A.M.
14 P.M.
15 A.M.
SAMPLES

equilibrium (*see* Scott, Paper No. IX). In the middle of the drying process at the end of the day the testa has actually a lower water content than the embryo, and at this stage the nightly increment in testæ water content is no doubt derived from the embryo.

A further interesting fact is revealed by this curve. The first five samples show an increase during the first and second nights, not only in the testa water content, but in the embryo water content also.

This may be due to the continuation of the acetic acid fermentation process for in this process water is liberated.

(That fermentation does continue in partly dried cacao when it is heaped up over night has been proved by observation).

In uninterrupted sun drying the water content of the testa is rapidly reduced, so that external mould growth is prevented or checked. During the night the testa absorbs moisture from the embryo and its water content rises, only to be again reduced in the next day's drying.

This train of events may easily be detected, in the earlier stages of drying, by touching the cacao.

When dry cacao is exposed to a damp atmosphere however we have seen that the testa very rapidly absorbs water, and that external moulds are able to grow. If we consider two lots of cacao of the same water content, one of which, originally dry, has been absorbing water while the other has been drying, it is obvious that in the former conditions are much more favourable to external growth and penetration of the testa (*see* section III) than in the latter.

In interrupted protracted drying the water content of the testa is not rapidly reduced, and conditions similar to those which occur in re-absorption obtain.

The results of Experiments XIV and XIIIB afford an interesting comparison. In Experiment XIV, Set 4 had approximately the same water content as in Experiment XIIIB, Set II. The former lot of cacao was exposed in a saturated atmosphere ; the latter was quickly dried to the required water content. In the former case the testa was nearly saturated and moulds grew on the outside of the beans, whereas in the latter case moulds did not appear on the outside of the testa and no moulding during the period of observation.

This fact is of practical importance, for it indicates that in stored cacao which is re-absorbing moisture more favourable conditions for moulding exist than in cacao which has been expeditiously dried to the same water content, owing to the higher water content of the testa in the former.

Further reference is made to these facts in section II.

The relation between the water contents of testa and embryo in the different conditions of active absorption, active drying, and equilibrium are shown in the correlation diagram in Plate XXVII the data being extracted from some of the experiments which have been described, and from further determinations of samples which have been allowed to reach equilibrium.

The results of the experiments which have been carried out provide important data. Among other facts which will be referred to later they show that internal moulding occurs after storage at a water content of 0.5 per cent., but not after prolonged storage at eight per cent. The critical water content therefore lies between these two figures. Further experiments, which limitations of time have not permitted, would probably result in a closer determination, but for all practical purposes this bracket is sufficiently close. Cacao with these end values of water content is at equilibrium in atmospheres of 82 and 87 per cent. saturation respectively (*See* Scott's equilibrium curve, Plate XVI in Paper No. IX). These facts are of importance not only in determining the extent to which cacao should be dried in the first instance, but also in considering questions of storage. (*See* section IV).

## II. THE CIRCUMSTANCES AND THE STAGES IN THE HISTORY OF THE PRODUCT IN WHICH CONDITIONS PERMITTING MOULDING OCCUR.

It has been seen that the factors of nutrition and temperature suitable for growth of moulds are provided by the cacao itself and by climatic conditions respectively. In the case of temperature, the optimum for *Aspergillus fumigatus* and *Mucor sp.* (C.B. 463) occurs in the fermentation process, and the optimum for the other moulds concerned in the normal range of air temperature.

The controlling factor however is that of the presence of water in quantity sufficient to permit growth. Cacao contains sufficient water to support mould growth in various circumstances and stages of preparation and handling—

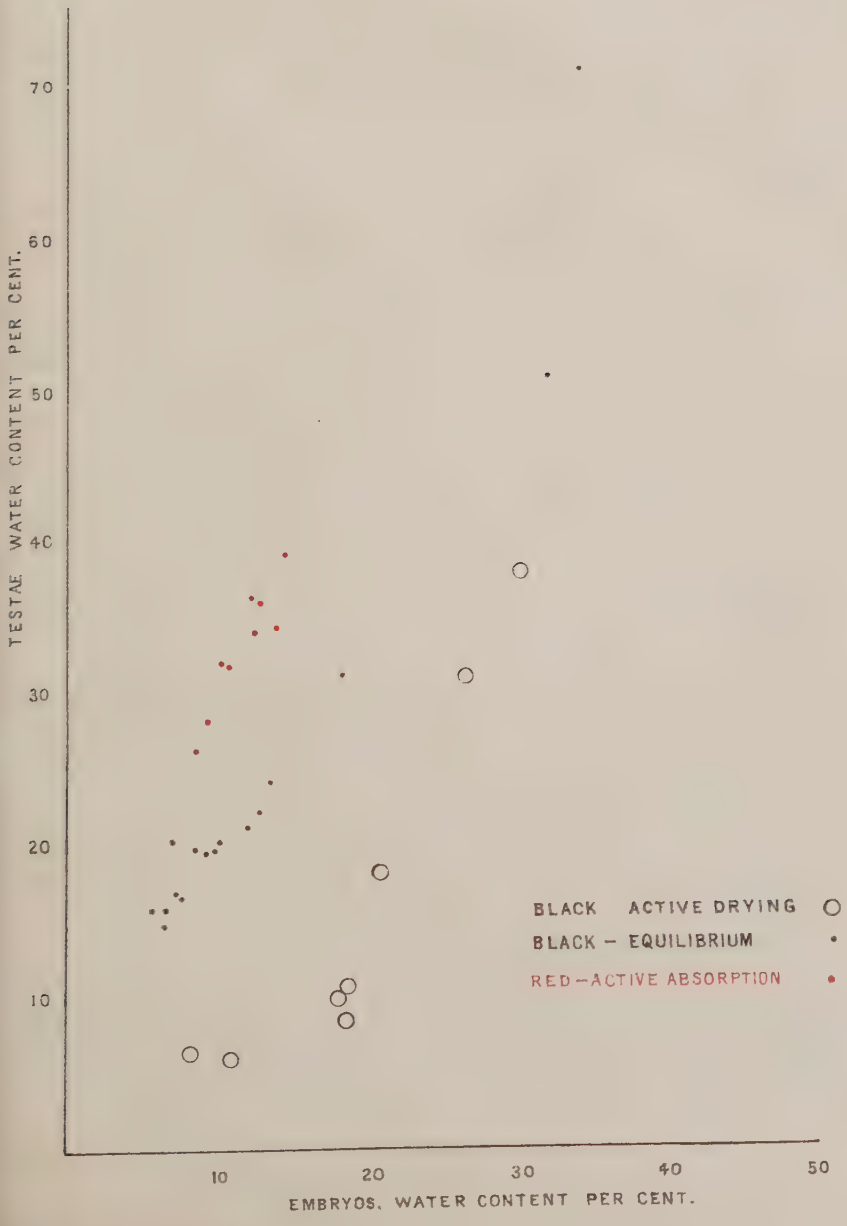
(*a*) During fermentation.

(*b*) During sun drying, before the water content has been reduced to below the limit necessary for growth.

(*c*) During storage if the atmospheric humidity is sufficiently high to permit absorption by the cacao reaching equilibrium at a water content exceeding the limit necessary for growth.

(*d*) During handling and transport if the cacao is accidentally wetted by rain or sea water.

CORRELATION DIAGRAM SHOWING RELATIVE WATER CONTENTS OF TESTAE AND EMBRYOS IN THE CONDITIONS OF EQUILIBRIUM. ACTIVE DRYING AND ACTIVE ABSORPTION.




Survey H.Q. Accra, 1929.

It is obvious that in all cacao except that in which the testa has been perforated mechanically or by germination the moulds must first grow on and in the testa before internal growth can ensue. (Any considerable appearance of external mould is a clear indication that internal moulding is at least incipient. Such external mould will however disappear in handling and further drying. Internal mould may disappear with drying if it has not progressed very far, but if dense felted mycelium is formed or if sporulation has occurred to any extent drying will not remove visible traces.)

It is therefore the water content of the testa which is critical rather than that of the whole bean. It has been seen in the experiments described in section I that the relation between the water contents of the testa and of the whole bean is not a fixed one. In steady atmospheric conditions the testa and embryo reach equilibrium. But the relation of the testæ content to that of the whole bean is very different in the case of cacao which is actively absorbing atmospheric moisture from what it is in cacao which is actively losing moisture. So that in two batches of cacao of the same whole-bean water content, in one case the testæ may be wet enough to permit mould growth while in the other they may be too dry. In its practical application this means that beans which are absorbing water from a very humid atmosphere become mouldy much more readily than others of the same water content which are drying.

The curve illustrating Experiment XIIIA shows that in a mass of drying cacao during the daily sun drying the testa water content is very low compared with the water content during the night, when it reaches equilibrium with the embryo. Thus in expeditious drying mould growth is inhibited during the day and internal infection does not take place.

## III. MEANS BY WHICH CACAO BEANS BECOME INFECTED INTERNALLY BY MOULD FUNGI.

Internal moulding can only ensue after penetration of the testa by the fungi concerned.

The testæ of a certain proportion of the beans are damaged, and in these cases there is no obstacle to the entrance of fungi. Damage is commonly caused by knife cuts during husking, by germination before preparation, by handling very dry cacao, in which the testæ are brittle, and by insects which infest prepared cacao

In beans which are thoroughly mouldy it is not easy to determine the site of infection. In those in which moulding has not yet proceeded too far the site of infection is usually conspicuous. From it the internal mycelium radiates, and fructification first occurs in its neighbourhood. Many thousands of such cases have

been examined, and in all cases except those in which the testa has suffered mechanical injury the mould spreads from a point in the testa opposite the tip of the radicle, up and around the radicle and on the adjacent surfaces of the cotyledons. A bean in this state is shown in figure 12 in Plate XII of Bunting's Paper No. VIII in this Year Book. If further growth is not checked by further drying of the bean the mould spreads all over the surface of the embryo, and finally the spaces between the cotyledons and their convolutions become densely packed with mycelium and spores

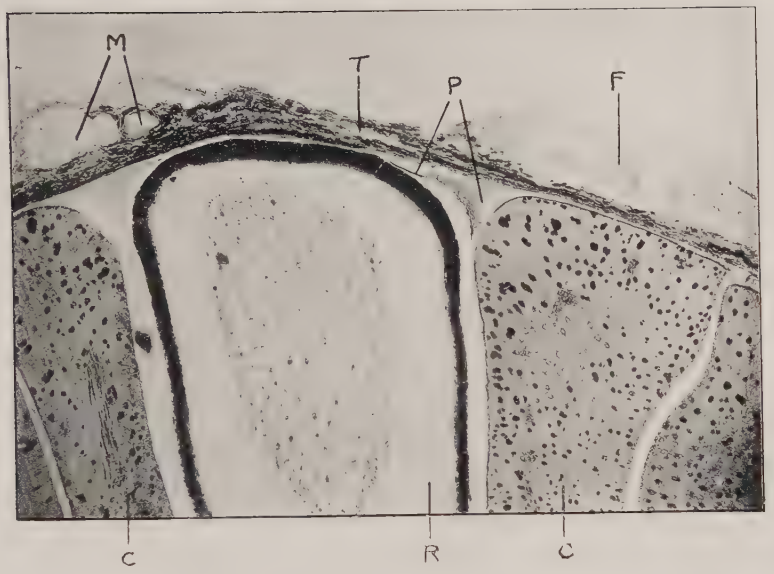
A few examples indicating the proportion of cases of moulding in which infection occurs at this site are given in Table VII below :—

TABLE VII.

| Total infections. | Micropylar infections. | Other sites of infection. (Testæ damaged). | Not determined. (Moulding complete). |
|---|---|---|---|
| 13 | 5 | 3 | 5 |
| 30 | 16 | 3 | 11 |
| 49 | 23 | — | 26 |
| 75 | 35 | — | 40 |
| 90 | 47 | — | 45 |
| 32 | 15 | — | 17 |
| 35 | 26 | 4 | 5 |
| 38 | 30 | 1 | 7 |
| 33 | 24 | 4 | 5 |
| 16 | 13 | 1 | 2 |
| 43 | 35 | — | 8 |

This phenomenon is of considerable interest, and has been investigated.

The anatomy of the testa in the region of the micropyle is shown in Plates XXVIII and XXIX. The micropyle does not remain open, and figure 2 in Plate XXVIII and figures 1–3 in Plate XXIX show the tissue by which it is closed. Above the micropyle a dome of rather thick-walled cells, some of which contain tannin, is formed. This is more or less elaborately developed—a well formed dome is seen in figures 1 and 2 in Plate XXIX Mucilage canals (M. fig. i Plate XXVIII and fig. i Plate XXIX) run through the testa on each side of the dome. The ovule of cacao is anatropous, and the hilum is therefore close to the micropyle. Therefore some sections—figure i in Plate XXVIII contain the remains of spiral elements of the funicular strand. Within the testa the remains of the perisperm persist as a thin membranous sheath-P, figure i Plate XXVIII and in other Plates—which surrounds the embryo and an annular



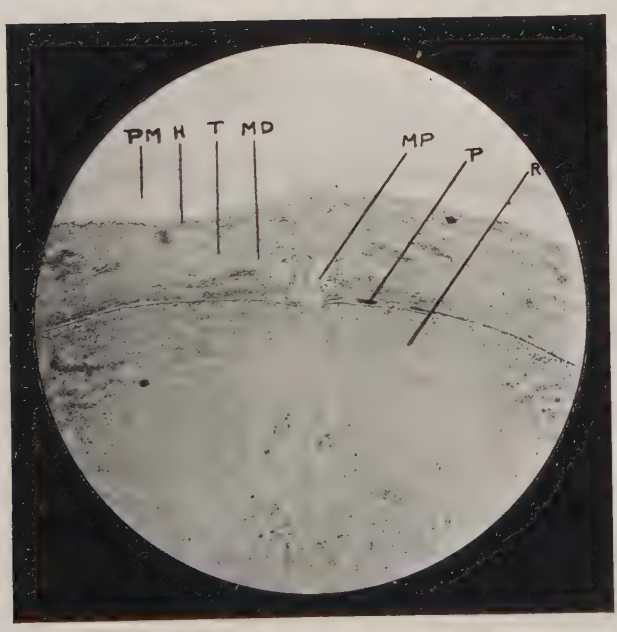
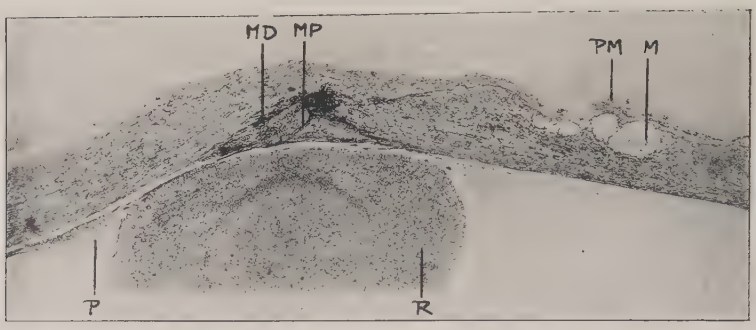




Fig. 1. L.S. fresh cacao bean near micropyle, × 21 d.

Fig. 2. L.S. fermented bean, through micropyle, × 54.3 d.

C, cotyledon; F, remains of funicular strand; H, hilum; M, mucilage canal; MD, micropylar dome; MP, plug; P, perisperm; PM, placental mucilage; R, radicle; T, testa.



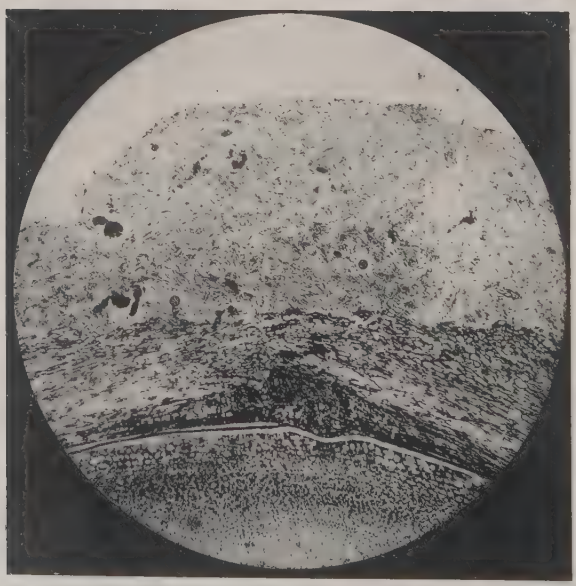


Fig. 1. L.S. fermented bean through micropyle, × 21 d., showing well-developed dome and plug.
Fig. 2. Detail from same section as Fig. 1, × 54.3 d.
Fig. 3 A similar section, × 54.3 d., showing yeasts in placental mucilage, and also conidia of *Trachysphaera fructigena*, indicating that the bean came from a diseased pod.

Lettering as in Plate XXVIII.

thickening of this membrane surrounds the tip of the radicle ("germ") while two wings project into the space between the two cotyledons. This membrane forms what is known as the "beeswing" of the bean.

When germination takes place the radicle does not cause an irregular rupture, but in emerging forces out a disc of the testa, thus making a clean circular hole just large enough for it to pass through. It therefore seems probable that a ring of weak or weakened tissue exists in the testa opposite to the circumference of the tip of the radicle. Whether this weakness may be structural or may be the result of enzymatic action at the time of germination is not known. Sections of beans in all stages, from those freshly removed from pods to fermented dried beans do not reveal any apparent structural differences between the testa walls in this and in other regions.

Numerous beans exhibiting external moulds were fixed and embedded, and microtome sections were cut. These preparations showed that penetration of the testa by some mould fungi occurs in the ring of tissue opposite the radicle. Plate XXX shows photomicrographs of a section which shows hyphae in the cells of the testa in this region, and figures 1 and 2, Plate XXXII show the testa cells packed with hyphæ of *A. fumigatus*, and a mass of mycelium bursting through into the inside of the bean.

Hyphae and perithecia of *A. glaucus* were found in many originally mould-free dried beans which had been exposed to a saturated atmosphere for six days. The hyphæ could be seen, with a lens, on the inside of the testa, emerging from the micropylar region, and the young perithecia were clustered in a ring around the depression, in the thicker part of the remaining perisperm, which is occupied by the tip of the radicle.

The fact that the cell walls of the testa in the region opposite the radicle offer less resistance to penetration by hyphæ of at least *A. fumigatus* and *A. glaucus* is therefore demonstrated. Other fungi may also be capable of entering the bean in the same way. This has not yet been investigated but it will be seen (vide infra) that in the case of other moulds the necessity for such penetration is probably not essential. Two of the important moulds, *A. tamari* and *A. flavus*, are not able to secrete enzymes which would enable them to penetrate cell walls.

The possibility that weakening of resistance to penetration may be due to other than mechanical causes is worthy of consideration. The secretion of enzymes which break down cell walls in this region and thus facilitate emergence of the radicle may occur in incipient germination. Incipient germination may, and almost certainly does, occur in the early stages of fermentation, at least in those beans on the outside of the fermenting mass, and is subsequently checked, by death brought about by heat, before

any measurable growth has occurred. In box fermentation the mixing of the mass allows at the most two days during which the process may go on in the extreme outside layers of the mass. In native fermentation heaps turning is not usually practised, and there is rather a longer period during which germination changes may occur in part of the mass. Occasionally, in heaps which are not thoroughly insulated, beans on the outside of the mass may be found in which germination has proceeded as far as emergence of the radicle. In the central part of the mass incipient germination, if it occurs at all, must be very quickly checked by rising temperature, and possibly by increasing concentration of carbon dioxide.

If weakening of the testa wall does take place in this way we should expect to find that some part of a batch of fermented cacao is much less resistant to moulding than the rest.

It is a significant fact that slatey (i.e., unfermented) beans are very rarely found to contain mould. In this case conditions favouring germination may not occur.

There appears to be some evidence in support of the theory that weakening of the testa in the micropylar region may be due to the action of enzymes secreted during incipient germination. For practical reasons it has not been possible to test this theory. If it were confirmed, it might be found that methods of preparation involving rapid killing of the embryo would result in a product more resistant to internal moulding. It is obvious that death of the complete batch occurs more quickly in stirred than in undisturbed fermentation masses.

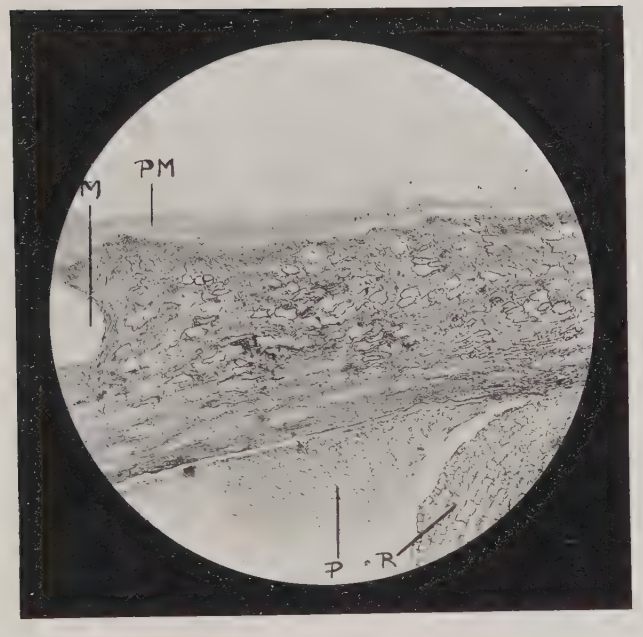
In fermentation heaps or boxes bacteria occur—especially in the former—and some of these may also play a part in weakening the testa. In normally fermented beans bacteria have however not been found penetrating the cells of the testa. In beans kept in an incubator at 40° C. for several days after fermentation was complete bacteria were found in the testa cells and inside the beans.

## IV. THE STAGE IN WHICH INFECTION OCCURS.

The infection of the outside of the bean commences at the moment of husking, for all the fungi concerned are ubiquitous. Growth proceeds on the placental mucilage.

Internal infection of the beans by moulds can occur at any stage after husking and during preparation and handling when the water content is sufficiently high*.

* These statements, while broadly true, need some qualification. (*a*) In the case of pods in which pod disease has proceeded very far before husking, beans are occasionally found which have been penetrated by pod disease fungi. The latter do not cause commercial moulding but by penetrating the testa provide a means of entrance for other fungi. (*b*) Infection possibly cannot occur, in spite of all other conditions being favourable, in slatey beans.



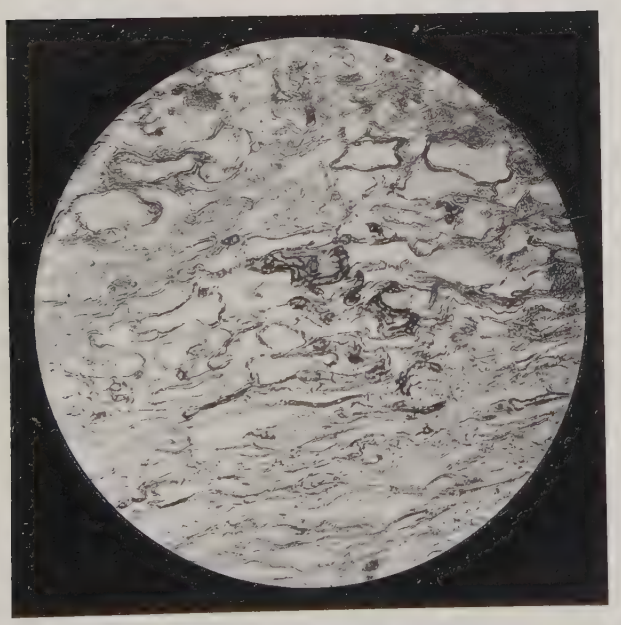



Fig. 1. L.S. fermented bean, × 54.3 d. Hyphae penetrating testa in the "weak" annular region opposite the circumference of the radicle.

Fig. 2. Detail from same section as Fig. 1, × 208 d.

Lettering as in Plate XXVIII.

PLATE XXXI.

A native fermentation heap after 6 days fermentation. Half the cacao has been removed, thus giving a sectional view of the middle of the heap. The zone of white, densely matted mycelium of *Mucor* sp. (463) and *Aspergillus fumigatus* is seen involving the outer layers of cacao, and sporulation on the surface of the heap can be seen on the extreme left.

In native fermentation heaps, which are not usually stirred during fermentation, only two fungi are found in quantity. These are *Aspergillus fumigatus* and *Mucor* (*Cymomucor*) nov. sp. 463, both thermophils, which thrive in the high temperatures of the fermenting mass, while the former actually raises its temperature. Plate XXXI shows the dense matted mycelium and the spore masses of these fungi in a native fermentation heap at the conclusion of fermentation. Half of the heap has been removed to show a section through the centre. The condition of this heap is quite typical. The central portion is more or less free from mycelium, which is highly developed on the outer four to seven inches of the top and sides of the heap, and less developed at the bottom. Apparently the high concentration of carbon dioxide inhibits free growth there. Luxuriant sporulation takes place on the surface of the heap, which is covered with a thick velvety grey mass of spores. This may be seen in the photograph on the small part of the surface which can be seen on the left side of the heap.

This growth of mould in the fermentation mass does not normally occur in boxes, in which the cacao is stirred every two days, nor in heaps which are stirred. Occasionally farmers include the placenta ("guts") in the freshly made heap, and remove them subsequently—after three or four days. In some cases this is not deliberately done with the object of improving fermentation, but because there was no time to separate placentæ on the formation of the heap; the effect is however beneficial—no appreciable mould growth forms in the heap and stirring results in more even fermentation. The visible mould and sporulation appears only during the last two days of fermentation in heaps which are not stirred.

Reference has been made in section 3 to the penetration of the testa by *A. fumigatus*. The preparation illustrated in fig. I, Plate XXXII is one of several made from beans taken from the outer layers of a heap on the sixth day of fermentation. It is then evident that this fungus is able to penetrate the testa—at least in the case of beans in the outer part of the heap—in a very short time. Other beans showed penetration of the testa by mycelium which could not be definitely identified, but there is little doubt that it was mycelium of the *Mucor* 463.

In a proportion of cacao, therefore, infection occurs actually during fermentation.

The rates of growth of *A. fumigatus* and *Mucor* 463 are slow, at air temperatures, compared with those of the other fungi concerned in moulding.

These two fungi are frequently found causing commercial moulding and in very many cases they are present in mouldy beans but are masked by other moulds, with which they cannot compete at ordinary temperatures, but which are no doubt secondary.

Large samples of incompletely dried fermented cacao were divided into two lots, one of which was kept at air temperature and the other incubated at 40° C. In the latter *A. fumigatus* and *Mucor* 463 were subsequently found both inside and outside all the beans. In the former lot they could be demonstrated in some of the beans, but all the beans were packed with other moulds, principally *A. flavus* and *A. tamari*.

The importance of *A. fumigatus* and *Mucor* 463 is not therefore limited to their occurrence as visible internal moulds, for there is no doubt that they precede other fungi, for which they may provide a means of entrance.

When fermentation is over, other moulds play the leading part, although it appears that to some extent the fungi of the fermentation heap facilitate their entrance.

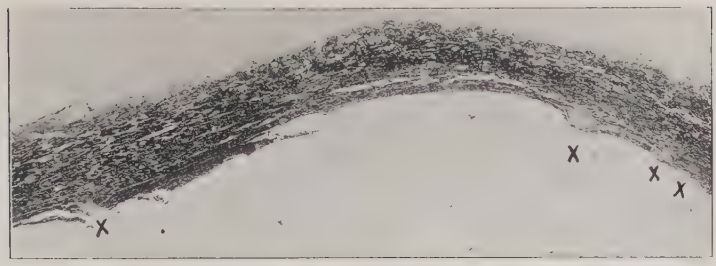
During the heavy and frequent rains which fall during the earlier part of the reaping season (i.e., normally until mid-December) sun-drying, which is the only method in use in the Gold Coast, is greatly hampered. Drying is often protracted sufficiently to permit commercial moulding before the necessary degree of dryness is attained. In one batch of native-prepared cacao which was under close observation at Anyinam, drying, owing to almost incessant rain, was not complete until 14 days after the cacao had been removed from the fermentation heap. On the fourteenth day the batch was sampled, some hundreds of beans being cut, the result showing that 30% of the batch was already commercially mouldy.

Such unavoidable delay is so common during September, October and November that there is no doubt whatever that it is responsible for a large proportion of the incidence of moulding.

The relative importance of infection in later stages—i.e., during transport and handling—is not known, sufficient data not being available. In up-country transport and handling, after the farmer has disposed of his cacao, precautions are taken by merchants to ensure thorough drying (if they are not satisfied that their purchase is sufficiently dry) and protection from rain. Cacao which is undergoing further drying in merchants' compounds is occasionally wetted by rain, but on the whole, in this stage there seems to be little possibility of infection by a further growth of moulds.

A preliminary collection of data regarding the water content of cacao in course of handling—*see* Scott's Paper No. IX—indicates clearly that a good deal of this cacao was distinctly above the limit of safe water content.

In the seasons of 1927 and 1928 the practice, by small traders, of purchasing wet freshly fermented cacao from farmers has been



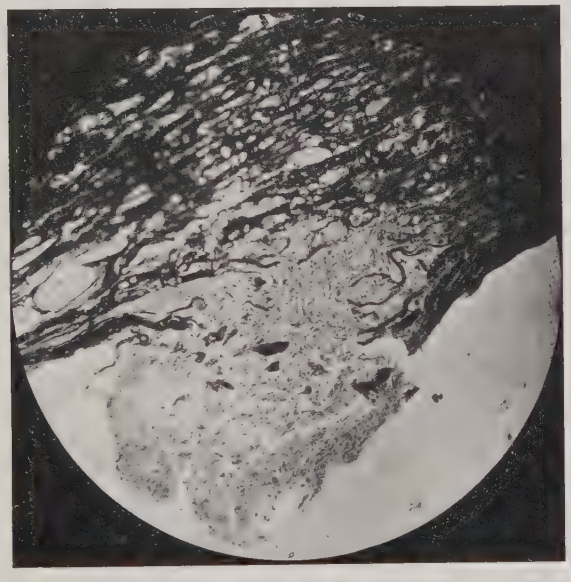



Fig. 1. Section through testa in neighbourhood of micropyle after 6 days fermentation in a native heap, × 21 d. Mycelial masses of *A. fumigatus* irrupting at X.

Fig. 2. Detail from a similar section, × 208 d. through an irruption. Testa cells are packed with mycelium.

Fig. 3. Detail from a similar section, × 208 d. Sporophores and spores of *A. fumigatus* inside the bean.

Lettering as in Plate XXVIII.

growing. This inevitably leads to delay in drying, while the cacao is transported from place to place, and increases the chances in favour of moulding.

In store, while awaiting transport or shipment, the question of absorption of atmospheric moisture arises.

A year's hygrometer record of the cacao store at Aburi, which is representative of stores in extremely high atmospheric humidity, shows that the average daily humidity fluctuates throughout the year excepting the dry season between 80 and 95 per cent. saturation*. We have seen that 82 per cent. saturation corresponds with a water content of cacao of 8 per cent., and that moulding does not occur at this point, but that 87 per cent. saturation corresponds with a water content of 9.5 per cent., at which moulding occurs.

The Aburi store is therefore definitely unsafe for protracted storage. An originally thoroughly dried bag of cacao was kept in this store for twelve months, at the end of which period it was found to contain a large percentage of internally mouldy beans. In the more humid types of store therefore cacao may in time acquire a water content which will permit moulding. In stores in drier conditions the same danger may not exist, but this can be known only by investigating the conditions of humidity of the store.

It is suggested that eight per cent. be regarded as the maximum water content permissible in marketed cacao, thus leaving a small margin of safety between eight per cent. and the critical point which lies between that and 9.5 per cent. A store having an average daily humidity of over 82 per cent. must then be regarded as unsafe for prolonged storage.

The period, at various degrees of humidity, for which it is safe to store cacao is not yet definitely known, though it is hoped that experiments which have been planned will provide more information. It will be seen that the problem is by no means a simple one. We know that the time factor is of importance because moulding takes place more slowly in drier samples than in wetter ones, so that as the critical water content is approached months may elapse before commercial damage is done. It may therefore be permissible to take risks in storing in an average humidity of slightly over 82 per cent. saturation. Again, we know that in laboratory experiments with small quantities of cacao (*see* Paper No. IX) the water content of the beans rapidly reaches

* The humidity curve for the store reproduced in Paper No. IX was recorded during the dry season, and the steadier portion of it (i.e., that recorded before the temporary fall in humidity caused by the incidence of " harmattan ") is distinctly lower than the normal steady curve for the major part of the year.

the equilibrium point determined by the humidity of the atmosphere. But conditions in such experiments are very different from those which obtain in actual commercial storage, where large numbers of bags are closely packed together. In such conditions it is reasonable to suppose that the outer layers of the very hygroscopic beans reach equilibrium with the atmosphere in a very short time, but that in doing so they do to some extent monopolise the available atmospheric moisture, and act to some extent as a protective layer to the inner layers of beans. At least, the inner beans will require a much greater time to reach equilibrium with the atmosphere of the store. There is some evidence to support this view. In the bag of cacao—to which reference has previously been made—which was stored at Aburi for a year, 50 per cent. of the beans on the outside of the bag were mouldy and only 17 per cent. of those in the middle of the bag. The bag was loosely packed and was frequently shifted on and off the steelyard on which it was weighed every day. Consequently much disturbance of the contents took place, and some of the outside beans were gradually worked into the middle, and *vice versa*. In an undisturbed bag kept in store for a shorter period more comparable with actual practice we may be reasonably certain that a much smaller percentage of moulding would take place, and that it would be confined more closely to the surface layers of beans. In stacked bags only the ends of bags are exposed. Experiments are planned for next season which should show clearly the degree of damage which will take place under practical conditions of storage.

In the operations preliminary to shipment and in ocean transport itself the risk of wetting is high.

That wetting by sea-water is as effective as by fresh water in promoting moulding was shown in laboratory tests by Bunting, and subsequently in bulk tests by Scott and Hudson (*see* Year Book 1927). Moulding may therefore occur to some extent during ocean transport but experimental shipments which have been made by the Department have not produced definite information on this point.

It must be clearly understood that the water content of a bag of cacao at any one time during its history is no indication of the moulding which may already have occurred or may in future occur.

For example cacao which has been subjected to delay in drying may contain a large percentage of mould, and subsequently be dried to a safe water content and pass through the merchants' hands in this state. The mould will still be present though further drying may cause its disappearance, from the commercial point of view, in beans in which only a little mycelial growth or sporulation has occurred.

In thoroughly mouldy beans—i.e., those in which dense mats of mycelium and profuse powdery masses of spores have been produced—thorough subsequent drying will not remove the visible mould.

On the other hand cacao fermented in a native heap will in part be infected internally, but after rapid and thorough drying no visible trace of mould may be found.

If however the water content be subsequently raised by wetting or absorption from the atmosphere development of the already present internal moulds may ensue; even if no external mould is evident.

External mould disappears in drying and handling, leaving no visible trace, so it is not possible to tell, by the external appearance of a sample, whether external moulding has previously occurred.

It is evident that the merchant can control moulding only by watching the water content of the cacao he handles, the humidity of his stores, and the conditions of transport, etc; he cannot directly control moulding which has already occurred before he purchases cacao.

## V. THE IDENTITY AND PROPERTIES OF THE FUNGI RESPONSIBLE FOR MOULDING.

This has been fully dealt with by Bunting in Paper VIII of this Year Book, and in this paper the properties of some of the fungi have been referred to in previous sections.

## VI. CONTROL.

A review of the phenomena of moulding and the circumstances under which they occur provides a basis for the consideration of means of control.

Owing to the nature and conditions of preparation and handling which obtain locally complete immediate control is not practicable, but it is evident that a very considerable reduction of the incidence of moulding could be obtained, the effect increasing with time, by—

i. Encouraging the stirring of the fermentation mass by native producers. (Improvement in fermentation methods and the eventual substitution of boxes for the present heaps is a feature of the policy of the Department of Agriculture. In cases where farmers are reluctant to adopt the box method, they might be persuaded, in the meantime, to stir heaps).

ii. Reducing, as far as possible by vigilance and care, the duration of drying when it is protracted by rain. (Attempts to obtain improvement in this respect also form a part of present activity of the Department of Agriculture).

iii. Devising some simple artificial means of drying to supplement sun-drying in periods of continuous rain.

iv. Adopting a standard of satisfactory dryness, for which 8% water content is suggested, and using a simple test for such thoroughly dried cacao.

v. Care in initial drying to standard by farmers.

vi. Care by local buyers in completing the drying of purchases which do not satisfy the standard, or refusal to buy cacao below this standard.

vii. More care in protection of cacao from rain in inland transport and handling.

viii. The storage only of thoroughly dried cacao, and its retention at standard dryness. The humidity of the store and the periods for which cacao is stored should be watched by merchants.

ix. Adequate protection of cacao waiting lighterage on the beach and in ocean transport.

Useful data are now at the disposal of merchants. Future experimental work which has been planned should provide further information on, for example, the question of the period during which storage is safe in stores in which the average daily humidity is slightly above the definitely safe value of 82 per cent. saturation.

In the meantime merchants would be well advised to obtain definite information on the humidity of their stores. The ordinary wet and dry bulb thermometers are not suitable for this purpose. A continuously recording hygrometer should be used, tracing a record on a chart which is renewed every week. Two types are available, the recording hair hygrometer and the recording wet and dry bulb hygrometer. The former gives direct readings of humidity in percentage saturation, the latter gives readings of temperatures of the wet and dry bulb thermometers. The former thus gives direct results but has the disadvantage of requiring frequent skilled adjustment. The latter is more reliable, but the data given by the two thermometer curves have to be interpreted by the aid of tables. The two types cost about £9 and £15 respectively. On the whole the recording wet and dry bulb instrument is perhaps the better of the two.

The following system of obtaining final results has been found satisfactory. From the completed weekly charts readings are extracted, for each day, for 12 midnight, 2, 4, 6, 8 and 10 a.m.,

12 noon, 2, 4, 6, 8, 10 p.m. The average of these is taken as representing the average humidity for the day. The average daily humidity is then graphed.

(More refined methods, based on the rates of absorption and drying of cacao in different degrees of saturation have been tried, but do not give in practice more useful results).

## VII. A TEST FOR DRY CACAO.

The ordinary methods in use by buyers for roughly testing marketed cacao do not appear to be accurate enough to determine whether the product has been dried sufficiently to prevent moulding.

It is very desirable that merchants who intend to store cacao should have some knowledge of the conditions of humidity of their stores, but it is of even greater importance to know with some certainty the degree of dryness of the cacao. Any of the ordinary methods of determining water-content take up too much time, or necessitate more or less elaborate apparatus and some skill in its use. Thus determination by one method entails drying small samples in a steam oven and accurate weighings on a chemical balance. In the toluene method the sample is weighed, boiled in an inflammable fluid in a rather complicated apparatus, much care and constant watching is necessary to control the distillation, and the water distilled is measured in a graduated cylinder. Such methods as these are not likely to be adopted by merchants and are properly laboratory operations.

The merchant who is going to store or ship cacao simply wants to know if it is sufficiently dry to remain free from mould. We have seen that cacao dried to eight per cent. water content is safe, while at 9.5 per cent. it is not. Some simple test which would show the difference between these two points without the use of complicated apparatus or skilled manipulation would be useful.

Numerous methods based on vapour pressure, specific gravity, and other physical phenomena suggest themselves but do not work in actual practice, with the exception of one which has been worked out by the writer. This is based on the equilibria which have been found to exist between atmospheric humidity and water content, and upon the colour change, from blue to pink, which takes place as dry cobalt chloride absorbs moisture from the air. Absorbent paper is soaked in a weak solution of cobalt chloride and dried. It has then a very faint pink or blue colour, according to the degree of atmospheric humidity. When it is warmed, water is driven off from the chloride and the paper acquires a vivid blue colour, which is again lost after a short exposure to the air. If two similar pieces of blued paper are exposed in two atmospheres of different humidity, that in the higher humidity loses its colour more quickly. If two samples of cacao of different water content are put into glass jars and allowed to reach equilibrium with the

small quantity of air also enclosed in the jars, the atmospheres of the jars in a short time reach a humidity corresponding with the water content of the cacao. If two pieces of blued cobalt chloride paper are dropped into the jars this difference in humidity is demonstrated by the different rates of change in the colour of the paper. In ordinary practice it is manifestly impracticable to use cacao of known water content as a standard against which to test other cacao, because obtaining the standard sample in the first place would require a series of laboratory determinations, and the water content of the standard sample not be maintained for long. We must therefore use an artificial standard. Standard solutions of various chemical substances could be used for this purpose, such as the potassium hydroxide solutions mentioned in Paper No. IX. But these require accurate preparation and do not remain at standard strength after frequent exposures to the air. A saturated solution of common salt however between 10° and 30° C. creates above it an atmospheric humidity of almost exactly 80 per cent. saturation, which corresponds to a water content of cacao of about 7.8 per cent. This is near enough to eight per cent. for the purpose, leaving a small margin of safety. All that is required for the standard therefore is a small quantity of wet salt. It is advisable to use salt of "Analytical Reagent" purity, which can be obtained from druggists at about 2/– per lb.

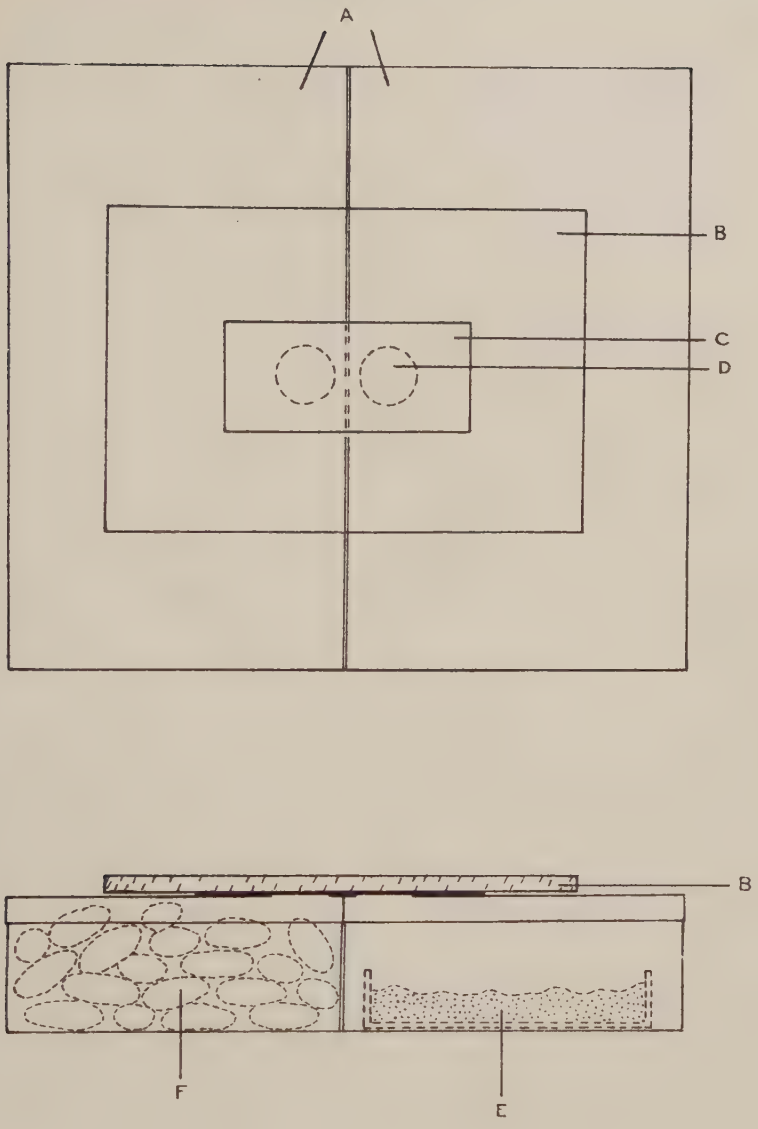
The test may now be applied, in its simplest form, by putting a sample of cacao to be tested and a small quantity of wet salt in two jars, and setting them aside for a short time to allow equilibrium to become established; a piece of cobalt paper is then warmed and torn in two, and half suspended in each of the two jars, the stoppers being replaced at once. If the paper in the cacao jar loses its colour more quickly than that in the salt jar, the cacao is too wet; if at the same rate, or more slowly, the cacao is sufficiently dry.

A more convenient method is to keep the wet salt in a small glass or glazed dish inside a small box—a flat rectangular cigarette tin of the size which holds 50 cigarettes is suitable. The cacao to be tested is put into a similar box. The lids, which should be a good fit, have each a circular hole, about half-an-inch in diameter, cut in them close to one side. The boxes are placed side by side with the holes together, and a piece of glass (plate glass is best because it is heavy and white) is placed over the holes.

After about a quarter of an hour a piece of cobalt paper is warmed until blue, quickly placed over the holes, and the glass replaced over the paper. The colour change takes place over the holes, and the two discoloured areas being close together they are easily compared. A result is obtained in about a minute.

A refinement consists in viewing the paper through a piece of red glass. This increases the contrast and makes the difference in the two fading discs more clear.

Plate XXXIII.




Apparatus for simple test for dryness.

A - Boxes, about 5" x 3" x 1".
B - Piece of plate glass.
C - Cobalt chloride paper.
D - Holes in lids of boxes.
E - Dish of wet salt.
F - Cacao to be tested.

Survey H.Q. Accra. 1929.

The test is accurate to within about one per cent. water content in the critical zone. That is to say, it is possible to distinguish between the standard and cacao of nine per cent. water content, and this degree of accuracy is sufficient for the purpose.

The test should be made in daylight. Samples of cacao to be tested should not be taken straight from drying mats, for then the testa is comparatively dry and the result will indicate a lower water content than is correct. Correct results are obtained from cacao which has been in store over night and in which equilibrium between testæ and embryos has been established.

No doubt further improvements could be made in the method of applying the test. Its advantages are obvious. It is quick and simple to carry out. The apparatus is cheap, and a large number of boxes could be installed if desired. For warming the paper a sheet of asbestos or similar material over a spirit lamp is satisfactory. The materials, salt and cobalt chloride paper, are also very cheap. The cobalt chloride paper would probably have to be specially prepared by a manufacturing chemist. A five per cent. solution applied to thin filter paper has given the best results. Thicker paper or a stronger solution makes contrast between the fading discs less easy to distinguish. The sheets should be about 2″ long and about 1″ wide, and must be evenly charged. Even charging is obtained by soaking large sheets and subsequently cutting them into smaller pieces. Special preparation would not add appreciably to the cost, and each sheet can be used several times.

A sketch of the apparatus made from cigarette boxes appears in Plate XXXIII.

## VIII. SUMMARY.

The work described above shows that—

1. The controlling factor in internal moulding of cacao is that of water content.
2. The fungus occurring most commonly as a " commercial mould " is *Aspergillus glaucus* (apparently *Chevalieri*).
3. *A glaucus* is able to grow and produce commercial moulding in cacao at a lower water content than the other fungi concerned.
4. In determining the degree of dryness necessary to prevent moulding, the percentage of water content which permit growth of *A. glaucus* is therefore critical.
5. This critical water content has been found to be between 8 and 9.5%, and cacao should therefore be dried to and retained at eight per cent. water content if it is to remain free from mould.

6. Conditions permitting moulding occur—
   (*a*) during fermentation
   (*b*) during drying which is protracted by rain
   (*c*) during storage when atmospheric humidity is sufficiently high
   (*d*) during handling and transport when cacao is wetted by rain or sea water.
7. Damage to the " shell " by husking knives, by insect pests, and by cracking in very dry cacao provide means of entrance of moulds to the inside of beans.
8. *A. fumigatus*, *A. glaucus* and probably *Mucor* 463, are able to penetrate the testa in the region opposite the radicle. The susceptibility of this part of the testa is possibly due to changes brought about by enzymatic action during incipient germination in the early stages of fermentation.
9. The fungi referred to in (8) are the most important of those causing internal moulding, *A. fumigatus* being able to penetrate the testa during fermentation and *A. glaucus* being able to penetrate the testa and to cause moulding at a lower degree of water content than any of the other fungi concerned.
10. These two fungi are very commonly found in mouldy beans, but are often overgrown by other moulds when the water content of the cacao is retained at a comparatively high value.
11. *A. fumigatus* and *A. glaucus* provide a means for the entrance of other moulds which are probably unable to penetrate the testa without this aid.
12. Infection by *A. fumigatus* (and probably by *Mucor* 463) occurs during fermentation at least in some proportion of the fermenting mass.
13. Internal infection by other moulds occurs during drying when this process is delayed by rain, and this is of frequent occurrence during the months of September, October and November—an important part of the season during which much of the preparation of cacao takes place.
14. Internal infection may also proceed in inland transport if cacao is wetted by rain. It may also occur during storage through absorption of atmospheric moisture.
15. A store with an average daily humidity of over 82 per cent. saturation is unsafe for the prolonged storage of cacao.
16. While complete and immediate control is not practicable, it is possible to obtain considerable reduction of moulding in a short time by methods for which suggestions are made.
17. By using the data and methods of observation now placed at their disposal merchants may obtain definite and useful practical information regarding their storage conditions and the state of the cacao in their possession.

PAPER No. XI.

# MEASUREMENT OF PLUMPNESS IN CACAO-BEANS.

By E. W. A. B. SAM.

Cacao, like other commercial products obtained from plants which have to go through certain processes of preparation before sale, exhibits qualities which enhance or greatly reduce its value.

In this country where the curing of cacao is not fully understood by the farmer on account of its recent introduction, a varying degree of quality is found in the prepared product.

Plumpness is one of the desirable qualities of cacao beans, as it suggests to the buyer good cultivation and careful preparation of the product.

## CAUSES OF PLUMPNESS.

Plumpness may be due to (*a*) good nutrition, (*b*) some inherent character of the parent tree to produce well filled beans, (*c*) proper curing processes.

Investigational work on the influence of each cause on the final degree of plumpness is necessary but does not fall within the scope of this paper, which is only an attempt to find a simple means of expressing the degree of plumpness by a numerical figure.

## EXPERIMENT TO OBTAIN FORMULA.

Measurements of a great number of cacao beans were made to find the relationship between the different dimensions, and their bearing on plumpness.

TABLE I.

*Flat beans.*

| Sample. | Length. | Breadth. | Thickness. | Calculated Vol. in cc. | Actual Vol. in cc. | Weight Grms. |
|---|---|---|---|---|---|---|
| 1 | 24.7 | 13.9 | 6.6 | 22.7 | 14.0 | 12.55 |
| 2 | 24.4 | 13.9 | 6.6 | 22.4 | 13.0 | 12.60 |
| 3 | 24.7 | 14.4 | 6.6 | 23.5 | 14.0 | 13.00 |
| 4 | 25.0 | 14.3 | 6.6 | 23.6 | 14.0 | 13.62 |
| 5 | 25.0 | 14.3 | 6.6 | 23.6 | 14.0 | 13.58 |
| 6 | 24.4 | 14.4 | 6.9 | 24.2 | 15.0 | 13.81 |
| 7 | 25.7 | 14.4 | 6.6 | 24.4 | 14.0 | 13.67 |
| 8 | 24.4 | 14.3 | 6.6 | 23.0 | 14.0 | 12.85 |
| 9 | 24.1 | 13.8 | 6.3 | 21.0 | 13.0 | 12.02 |
| 10 | 24.7 | 14.3 | 6.6 | 23.3 | 14.0 | 13.09 |

*Plump beans.*

| Sample. | Length. | Breadth. | Thickness | Calculated Vol. in cc. | Actual Vol. in cc. | Weight Grms. |
|---|---|---|---|---|---|---|
| 1 | 23.3 | 12.7 | 9.5 | 28.1 | 16.0 | 13.37 |
| 2 | 22.8 | 12.5 | 9.8 | 27.9 | 15.0 | 12.95 |
| 3 | 23.2 | 13.0 | 9.5 | 28.6 | 16.0 | 13.65 |
| 4 | 23.2 | 12.7 | 9.2 | 27.1 | 15.0 | 12.71 |
| 5 | 23.3 | 12.5 | 9.8 | 28.5 | 16.0 | 13.75 |
| 6 | 23.8 | 12.5 | 9.4 | 28.0 | 16.0 | 13.60 |
| 7 | 22.5 | 12.7 | 9.5 | 27.1 | 16.0 | 13.35 |
| 8 | 23.6 | 12.5 | 9.2 | 27.1 | 16.0 | 13.45 |
| 9 | 22.5 | 12.5 | 9.4 | 26.4 | 16.0 | 13.12 |
| 10 | 23.8 | 12.5 | 8.8 | 26.2 | 16.0 | 13.15 |

The above figures are a few of several samples measured from the same bag and give a fair picture of the whole.

It will be noticed from a study of them that flat beans are longer and broader than plump beans per unit of thickness. That comparing their weights relative to their actual volumes plump beans are much lighter than flat beans. Their specific weights being 0.84 and 0.94 respectively in the above samples.

These facts would appear to support the view that plump beans are in some cases the result of good fermentation coupled with a gradual process of drying, since during fermentation beans get blown out, becoming much fatter than they originally were, and that this state of distention is maintained if the drying is carefully carried out.

## METHOD EMPLOYED IN MEASUREMENT.

It would not be out of place, here, to explain how these measurements were obtained.

A sample consists of 10 beans ; these are placed end to end in a straight line and measured for length, the measurement being expressed in centimeters.

They are then placed broadside on, that is, side by side on their backs, and the row measured for breadth. To measure thickness, two pins are usually fixed at one end of the table at a distance of about $\frac{1}{4}$ of an inch apart, and against these the beans are placed on edge, care being taken that no gaps are left between the beans.

It may be mentioned that this is the system adopted for measuring cacao beans at ports of inspection.

PLATE XXXIV.

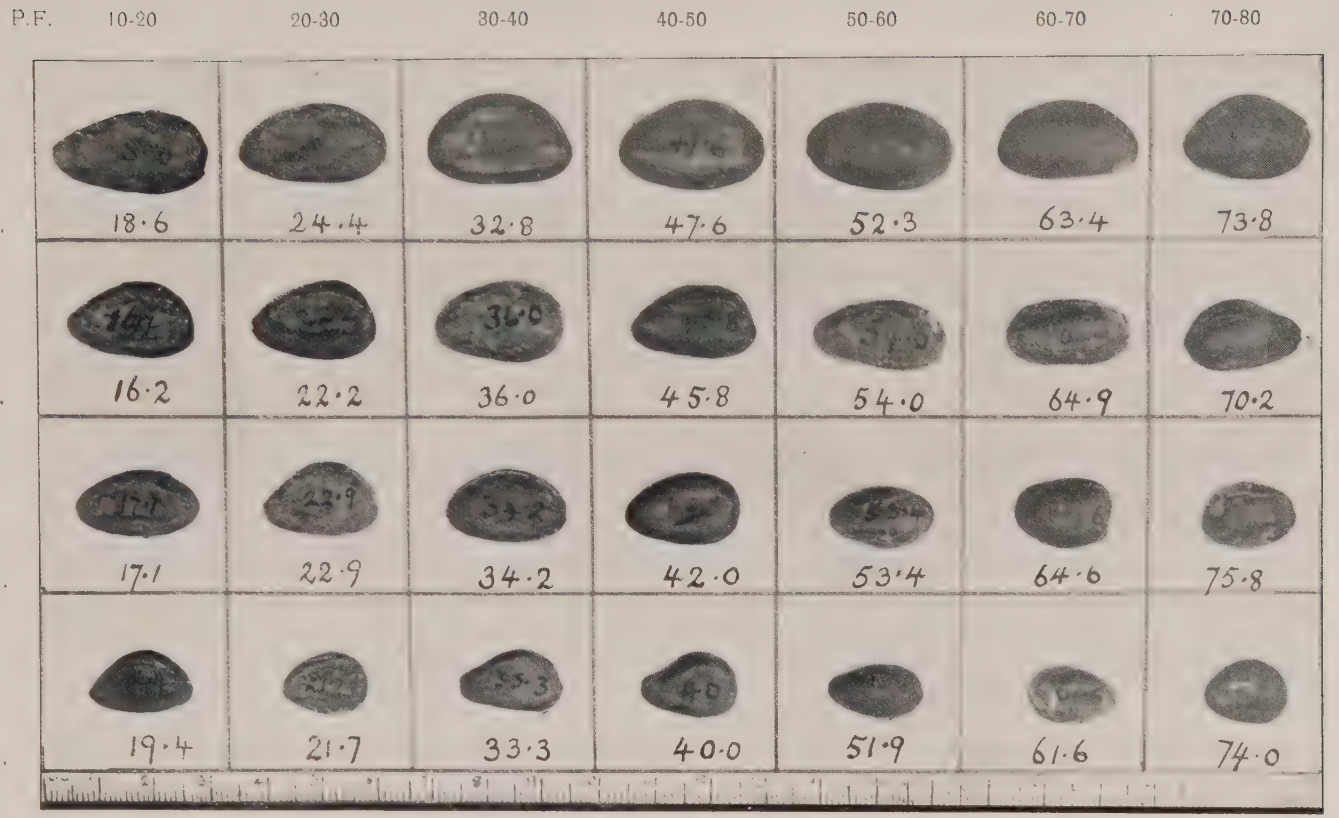



*Photo by J. A. C. Holm.*

CACAO BEANS OF FOUR DIFFERENT LENGTHS GROUPED ACCORDING TO PLUMPNESS.

PLATE XXXV.

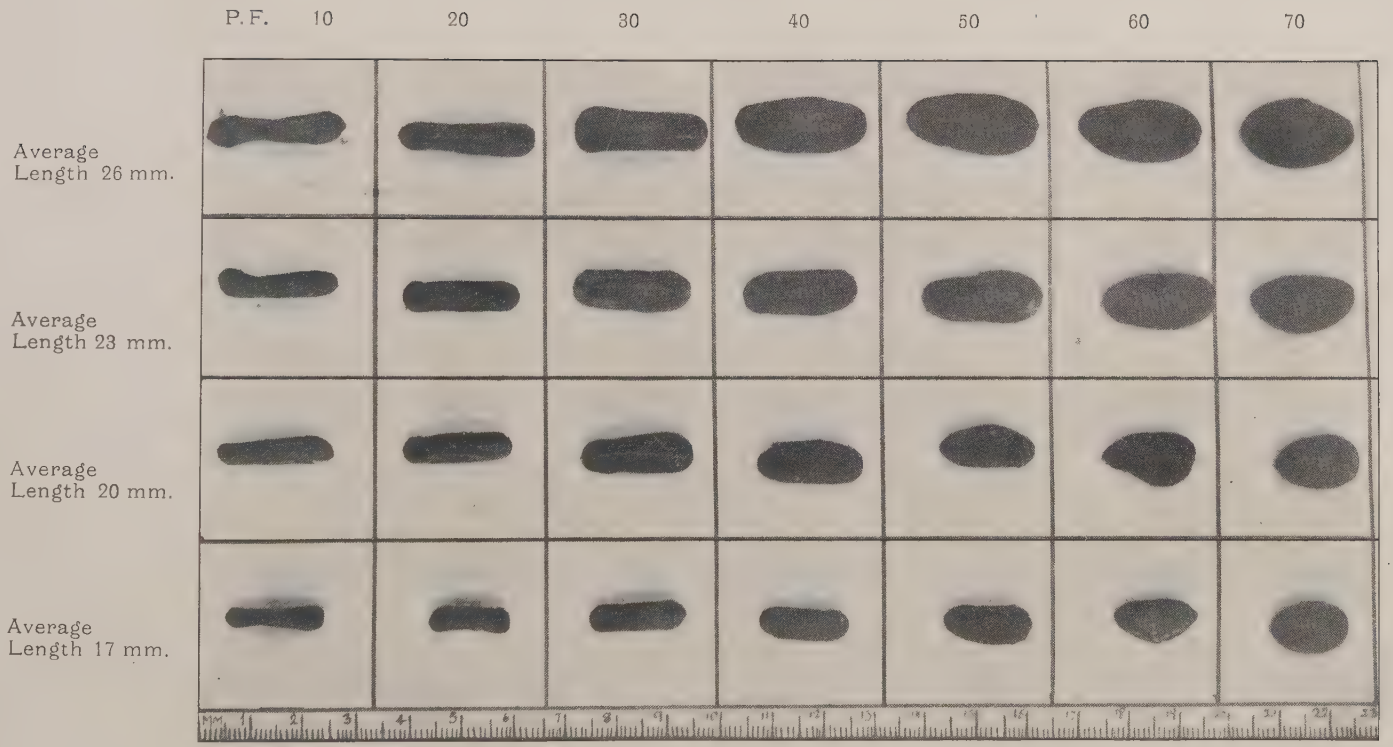



*Photo by J. A. C. Holm.*

EDGE-VIEW OF BEANS ON PLATE XXXIV.

In some of the experiments it was found necessary to measure the beans individually. This was carried out by means of a pair of calipers. In these measurements the length was taken as the longest distance between the two extremities of a bean (from the mycropile end to a point opposite it).

The measurement of a line drawn transversely across the broad side of a bean, and equidistant from the two extreme points marking the length, was taken as the breadth.

Thickness is the depth of the bean and is measured from two opposite points at the intersection of lines denoting length and breadth.

These points are arbitrary but it is believed that they express all that these three measurements stand for better than any other method.

## MEASUREMENT OF VOLUME.

The calculated volume is found from the three dimensions already obtained by measurements. It was found however to be useless as far as comparisons between plump and flat beans were concerned.

It is quite obvious that the cubic contents of a plump bean as calculated from its dimensions are much greater than its actual volume. In the case of flat beans, the error is much smaller so that relative to their weights flat beans appear much heavier per unit of volume.

The actual volume was found in this way :—a graduated measuring cylinder of fair size and wide enough to allow all sized beans to be easily introduced into it, was filled to a definite volume (50 cc. was found to answer well), with fine dry sand, which had been passed through a sieve of 60 meshes to the inch. The cylinder was tapped on a table until the reading remained constant. It was found that sand of the degree of fineness as given above will lose about 5% of its original volume.

The sand was next poured out, carefully avoiding any loss, and the beans, the volume of which was to be ascertained, introduced into the cylinder. Next the sand was poured gently into the cylinder and tapped to constant volume. The volume of the beans was thus the difference between the final and initial readings.

Sand is preferred to a liquid medium because :—

(i) It does not wet the beans.

(ii) There is no error due to absorption by the beans.

(iii) It is expeditious. In the case of a liquid medium the initial reading must always be corrected after each reading, on account of the amount of the medium the beans are likely to take away adhering to their surfaces.

(iv) The liquid medium must of necessity possess a low density for the beans to sink. Such a medium will be constantly evaporating, will be probably inflammable and generally unsatisfactory.

The disadvantages of sand are :—

(i) Error due to pore space. An error greatly minimised by using sand which has been passed through a 60 meshes to the inch sieve. Sand finer than this may be used with advantage.

(ii) Error due to a wide and uneven meniscus.

Another medium that could be used is mercury. In this case a plunger with a graduated stem might be provided for keeping the beans submerged, should an open graduated cylinder similar to the one used in these experiments be adopted.

## VALUATIONS AND POSSIBLE ERRORS.

After measuring over 3,000 beans from several consignments, it was found that the number of beans having double the length of any one bean is negligible. The same results were obtained in the case of breadth.

It was found however that the thickness of beans varies considerably, and that beans of double and treble the thickness of any one bean were very common in any ordinary sample.

To give an illustration, in one case ten beans were taken at random and out of the ten, nine were normal flat beans, and one had double the thickness; and though the variation in length and breadth were not great, it appeared in the case of thickness that the average was that of eleven flat beans and not ten.

The object of the foregoing experiment was to find whether a definite ratio existed between the thickness of beans and their actual volumes. The actual volumes being found by the sand displacement method.

## DETERMINATION OF A SUITABLE FORMULA.

100 plump and 100 flat beans were selected and measured for thickness 10 at a time.

## TABLE II.

*Plump beans.*

| Sample. | Thickness cm. | Actual volume cc. | Ratio $\frac{V}{T.}$ |
|---|---|---|---|
| 1 | 9.5 | 16.0 | 1.6 |
| 2 | 9.3 | 15.0 | 1.6 |
| 3 | 9.6 | 16.0 | 1.6 |
| 4 | 9.7 | 16.0 | 1.6 |
| 5 | 9.4 | 15.0 | 1.6 |
| 6 | 9.4 | 15.0 | 1.6 |
| 7 | 9.7 | 16.0 | 1.6 |
| 8 | 9.8 | 15.0 | 1.5 |
| 9 | 9.3 | 15.0 | 1.6 |
| 10 | 9.7 | 14.0 | 1.4 |

In both samples 8 and 10, the beans were short and stumpy.

*Flat beans.*

| Sample. | Thickness cm. | Actual volume cc. | Ratio $\frac{V}{T.}$ |
|---|---|---|---|
| 1 | 6.4 | 14.0 | 2.2 |
| 2 | 6.6 | 14.0 | 2.1 |
| 3 | 5.8 | 12.0 | 2.1 |
| 4 | 5.8 | 12.0 | 2.1 |
| 5 | 6.2 | 13.0 | 2.1 |
| 6 | 6.2 | 13.0 | 2.1 |
| 7 | 6.3 | 13.0 | 2.0 |
| 8 | 6.1 | 12.5 | 2.0 |
| 9 | 6.3 | 13.0 | 2.0 |
| 10 | 6.0 | 12.0 | 2.0 |

From these results it would appear that the beans having the ratio of over two are flat, and those, anything below 1.7, plump.

On using small beans the ratio is found to be different; instead of 2 and above for flatness the ratio was 1.3. See table below, Nos. 8, 9 and 10.

TABLE III.

| Sample. | Length cm. | Breadth cm. | Thickness cm. | Actual Vol. cc. | Ratio $\frac{V}{T}$ |
|---|---|---|---|---|---|
| 1 | 23.9 | 13.8 | 6.1 | 12.5 | 2.0 |
| 2 | 23.7 | 13.1 | 5.9 | 11.0 | 1.9 |
| 3 | 23.3 | 13.1 | 6.1 | 12.0 | 2.0 |
| 4 | 23.6 | 13.4 | 6.1 | 12.0 | 2.0 |
| 5 | 24.7 | 13.5 | 6.3 | 13.0 | 2.1 |
| 6 | 24.5 | 13.4 | 6.0 | 12.0 | 2.0 |
| 7 | 24.3 | 13.2 | 6.2 | 12.0 | 1.9 |
| 8 | 20.4 | 11.6 | 4.6 | 6.0 | 1.3 |
| 9 | 19.8 | 12.0 | 4.5 | 6.0 | 1.3 |
| 10 | 19.7 | 12.0 | 4.5 | 6.0 | 1.3 |

On examining the other dimensions however, the ratio of thickness to length in No. 6 is approximately 1:4, and has a factor of 2 ; and in No. 10 the ratio is also 1:4 but the factor is 1.3; both these beans appear equally flat.

Whereas the ratio of thickness to volume does not, that of thickness to length does seem to agree with actual observation.

Using the ratio of thickness to length, the following trials were made to find how far the variation in the degree of plumpness agrees with observed facts :—

(1) Ten flat beans were measured up and the measurements recorded. See Table below.

(2) Two plump beans were substituted for two flat ones and measurements again taken.

(3) Four plump beans were substituted.

(4) Six plump beans were substituted.

(5) Eight plump beans were substituted.

(6) Ten plump beans were substituted.

TABLE IV.

| No. of Sample. | Length cm. | Breadth cm. | Thickness cm. | Ratio $\frac{L}{T}$ |
|---|---|---|---|---|
| 1 | 23.2 | 13.3 | 6.0 | 3.9 |
| 2 | 23.6 | 13.0 | 6.9 | 3.4 |
| 3 | 24.0 | 13.0 | 7.8 | 3.1 |
| 4 | 23.7 | 13.0 | 8.7 | 2.7 |
| 5 | 23.0 | 13.0 | 9.7 | 2.4 |
| 6 | 21.8 | 12.5 | 10.8 | 2.0 |

It will be noticed that whereas the variation in length and breadth was small the thickness varied within very wide limits.

Below, is the result of a similar trial made with very small beans.

Ten flat beans were selected and measured, then two plump beans were substituted at a time until sample No. 6 consisted of nothing but plump beans.

TABLE V.

| No. of Sample. | Length cm. | Breadth cm. | Thickness cm. | Ratio $\frac{L}{T}$ |
|---|---|---|---|---|
| 1 | 19.5 | 11.5 | 4.0 | 4.9 |
| 2 | 19.1 | 11.5 | 5.0 | 3.8 |
| 3 | 19.4 | 12.0 | 6.5 | 3.0 |
| 4 | 19.2 | 11.2 | 7.6 | 2.5 |
| 5 | 19.0 | 11.9 | 9.0 | 2.1 |
| 6 | 19.2 | 12.1 | 10.5 | 1.8 |

In both trials, the variation is quite normal and agrees with the facts.

In the first case with cacao beans which were quite large in size, the degree varied between 2.0 and 3.9 ; a matter of 1.9 points.

In the case of the small beans between 1.8 and 4.9, i.e., 3.1 points.

This also agreed with the facts. The plump beans in the second trial were nearly spherical and the flat beans were exceptionally thin. The " flat " beans in the first trial were more medium than flat.

Up to this point the breadth had been ignored, but after a careful examination of a large number of figures, it was found that the variation was large enough to modify the $\frac{L}{T}$ ratio for plumpness.

On referring to the above table there will be found to be a difference of 9 mm. in breadth between samples 6 and 4; a fact which cannot be overlooked.

---

Consider two cacao beans A and B having similar lengths and thicknesses $T_1$ and $T_2$ but B having double the breadth of A.

It is quite obvious that A will appear plumper than B.

Suppose $b_1 = T_1$
then $b_2 = 2T_2$

hence to express the degree of plumpness as affected by breadth,

A will have a ratio of 1 : 1
and B ,, ,, 1 : 2

The closer the ratio the plumper the bean.

An equation can now be written which will involve all three dimensions.

Let L = length
b = breadth
T = thickness

then $\frac{\frac{L}{T} + \frac{b}{T}}{2} = \frac{L + b}{2T}$ = plumpness of any bean irrespective of shape or size.

This will give the plumpness in diminishing quantities, i.e., the greater the plumpness the smaller will be the factor figure.

Several individual beans were tested by means of this equation and it was found to work with a fair degree of accuracy.

On page 112 is the specimen of a table drawn up to represent the plump factors of different sized beans. In the table the factor figures are inverted and expressed in percentage using the formula

$$100 \left[ \frac{1}{\frac{L + b}{2T}} \right]$$

In this way we get the factors varying directly as the plumpness. The second table is a complete and abridged form of the first. On the right hand side is the sum of L and b. On top the thickness. Thus to find the plump factor of a bean it is only necessary to measure the length, breadth and thickness. Suppose the sum of length and breadth = 40, and thickness = 5, then the plump factor of that bean is 25 expressed as a percentage.

TABLE VI.

| L + b. | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 32+16 | 8.3 | 12.5 | 16.6 | 20.8 | 25.0 | 28.1 | 33.3 | 37.5 | 41.7 | 45.8 | 50.0 |
| 32+15 | 8.5 | 12.8 | 17.0 | 21.3 | 25.6 | 29.7 | 34.0 | 38.4 | 42.6 | 46.7 | 51.2 |
| 32+14 | 8.7 | 13.0 | 17.4 | 21.7 | 26.0 | 30.4 | 34.8 | 39.0 | 43.4 | 47.8 | 52.0 |
| 32+13 | 8.8 | 13.3 | 17.8 | 22.2 | 26.6 | 31.1 | 35.6 | 39.9 | 44.4 | 48.8 | 53.2 |
| 32+12 | 9.3 | 13.6 | 18.1 | 22.7 | 27.2 | 31.8 | 36.2 | 40.8 | 45.4 | 50.0 | 54.4 |
| 32+11 | 9.3 | 13.9 | 18.6 | 23.3 | 27.8 | 32.6 | 37.2 | 41.7 | 46.6 | 51.3 | 55.6 |
| 32+10 | 9.5 | 14.3 | 19.0 | 23.8 | 28.6 | 33.3 | 38.0 | 42.9 | 47.6 | 52.3 | 57.2 |
| 32+ 9 | 9.7 | 14.6 | 19.3 | 24.4 | 29.2 | 34.1 | 38.6 | 43.8 | 48.8 | 53.8 | 58.4 |
| 31+16 | 8.5 | 12.8 | 17.0 | 21.3 | 25.6 | 29.7 | 34.0 | 38.4 | 42.6 | 46.7 | 51.2 |
| 31+15 | 8.7 | 13.0 | 17.4 | 21.7 | 26.0 | 30.4 | 34.8 | 39.0 | 43.4 | 47.8 | 52.0 |
| 31+14 | 8.8 | 13.3 | 17.8 | 22.2 | 26.6 | 31.1 | 35.6 | 39.9 | 44.4 | 48.8 | 53.2 |
| 31+13 | 9.3 | 13.6 | 18.1 | 22.7 | 27.2 | 31.8 | 36.2 | 40.8 | 45.4 | 50.0 | 54.4 |
| 31+12 | 9.3 | 13.9 | 18.6 | 23.3 | 27.8 | 32.6 | 37.2 | 41.7 | 46.6 | 51.3 | 55.6 |
| 31+11 | 9.5 | 14.3 | 19.0 | 23.8 | 28.6 | 33.3 | 38.0 | 42.9 | 47.6 | 52.3 | 57.2 |
| 31+10 | 9.7 | 14.6 | 19.3 | 24.4 | 29.2 | 34.1 | 38.6 | 43.8 | 48.8 | 53.8 | 58.4 |
| 31+ 9 | 10.0 | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 | 50.0 | 55.2 | 60.0 |
| 30+16 | 8.7 | 13.0 | 17.4 | 21.7 | 26.0 | 30.4 | 34.8 | 39.0 | 43.4 | 47.8 | 52.0 |
| 30+15 | 8.8 | 13.3 | 17.8 | 22.2 | 26.6 | 31.1 | 35.6 | 39.9 | 44.4 | 48.8 | 53.2 |
| 30+14 | 9.3 | 13.6 | 18.1 | 22.7 | 27.2 | 31.8 | 36.2 | 40.8 | 45.4 | 50.0 | 54.4 |
| 30+13 | 9.3 | 13.9 | 18.6 | 23.3 | 27.8 | 32.6 | 37.2 | 41.7 | 46.6 | 51.3 | 55.6 |
| 30+12 | 9.5 | 14.3 | 19.0 | 23.8 | 28.6 | 33.3 | 38.0 | 32.9 | 47.6 | 52.3 | 57.2 |
| 30+11 | 9.7 | 14.6 | 19.3 | 24.4 | 29.2 | 34.1 | 38.6 | 33.8 | 48.8 | 53.8 | 58.4 |
| 30+10 | 10.0 | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 | 50.0 | 55.2 | 60.0 |
| 30+9 | 10.3 | 15.4 | 20.5 | 25.6 | 30.8 | 36.0 | 41.0 | 46.2 | 51.2 | 56.5 | 61.6 |

## TABLE VII.

| Σ L+b | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 8.3 | 12.5 | 16.6 | 20.8 | 25.0 | 28.1 | 33.3 | 37.5 | 41.7 | 45.8 | 50.0 |
| 47 | 8.5 | 12.8 | 17.0 | 21.3 | 25.6 | 29.7 | 34.0 | 38.4 | 42.6 | 46.7 | 51.2 |
| 46 | 8.7 | 13.0 | 17.4 | 21.7 | 26.0 | 30.4 | 34.8 | 39.0 | 43.4 | 47.8 | 52.0 |
| 45 | 8.8 | 13.3 | 17.8 | 22.2 | 26.6 | 31.1 | 35.6 | 39.9 | 44.4 | 48.8 | 53.2 |
| 44 | 9.3 | 13.6 | 18.1 | 22.7 | 27.2 | 31.8 | 36.2 | 40.8 | 45.4 | 50.0 | 54.4 |
| 43 | 9.3 | 13.9 | 18.6 | 23.3 | 27.8 | 32.6 | 37.2 | 41.7 | 46.6 | 51.3 | 55.6 |
| 42 | 9.5 | 14.3 | 19.0 | 23.8 | 28.6 | 33.3 | 38.0 | 42.9 | 47.6 | 52.3 | 57.2 |
| 41 | 9.7 | 14.6 | 19.3 | 24.4 | 29.2 | 34.1 | 38.6 | 43.8 | 48.8 | 53.8 | 58.4 |
| 40 | 10.0 | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 | 50.0 | 55.2 | 60.0 |
| 39 | 10.3 | 15.4 | 20.5 | 25.6 | 30.8 | 36.0 | 41.0 | 46.2 | 51.2 | 56.5 | 61.6 |
| 38 | 10.5 | 15.8 | 21.1 | 26.3 | 31.6 | 36.9 | 42.2 | 47.4 | 52.6 | 57.8 | 63.2 |
| 37 | 10.8 | 16.2 | 21.6 | 27.0 | 32.4 | 37.9 | 43.2 | 48.6 | 54.0 | 59.5 | 64.8 |
| 36 | 11.1 | 16.6 | 22.2 | 27.8 | 33.2 | 38.9 | 44.4 | 49.8 | 55.6 | 61.0 | 66.4 |
| 35 | 11.4 | 17.1 | 22.9 | 28.6 | 34.2 | 40.0 | 45.8 | 51.3 | 57.2 | 62.9 | 68.4 |
| 34 | 11.8 | 17.7 | 23.5 | 29.4 | 35.4 | 41.1 | 47.0 | 53.1 | 58.8 | 64.9 | 70.8 |
| 33 | 12.1 | 18.1 | 24.3 | 30.3 | 36.2 | 42.3 | 48.6 | 54.3 | 60.6 | 66.6 | 72.4 |
| 32 | 12.5 | 18.8 | 25.0 | 31.3 | 37.6 | 43.7 | 50.0 | 56.4 | 62.6 | 68.9 | 75.2 |
| 31 | 12.9 | 19.4 | 25.8 | 32.3 | 38.8 | 45.2 | 51.6 | 58.2 | 64.6 | 70.9 | 77.6 |
| 30 | 13.3 | 20.0 | 26.7 | 33.3 | 40.0 | 46.7 | 53.4 | 60.0 | 66.6 | 73.5 | 80.0 |
| 29 | 13.8 | 20.7 | 27.6 | 34.5 | 41.4 | 48.3 | 55.2 | 62.1 | 69.0 | 75.8 | 82.8 |
| 28 | 14.3 | 21.4 | 28.6 | 35.7 | 42.8 | 50.0 | 57.2 | 64.2 | 71.4 | 78.7 | 85.6 |
| 27 | 14.8 | 22.2 | 29.7 | 37.0 | 44.4 | 51.8 | 59.4 | 66.6 | 74.0 | 81.3 | 88.8 |
| 26 | 15.4 | 23.1 | 30.8 | 38.5 | 46.2 | 53.8 | 61.6 | 69.3 | 77.0 | 84.7 | 92.4 |
| 25 | 16.0 | 24.0 | 32.0 | 40.0 | 48.0 | 56.0 | 64.0 | 72.0 | 80.0 | 88.5 | 96.0 |
| 24 | 16.6 | 25.0 | 33.3 | 41.7 | 50.0 | 58.5 | 66.6 | 75.0 | 83.4 | 91.7 | 100.0 |

## LENGTH IN RELATION TO PLUMPNESS.

The method of division into grades of length and degrees of plumpness is shown in Plates XXXIV and XXXV. In Plate XXXIV the beans are shown lying on their sides so that the grading according to length is the main feature. In Plate XXXV the beans are lying on their edges so that the degrees of plumpness become very evident. In arranging the beans for illustration it has been necessary to introduce the grading of length although no actual standard by measurement has been employed, the beans in each class being selected by inspection and being of roughly the following length-classes.

| | | |
|---|---|---|
| Class | 1 | 24—28 mm. and over. |
| ,, | 2 | 22—24 ,, |
| ,, | 3 | 19—22 ,, |
| ,, | 4 | 15—19 ,, |

While it is obvious that intermediate types between any two classes may occur and also intermediate degrees of plumpness it seemed necessary to simplify the whole thing by making four classes and keeping the factors of plumpness down to order of significance. It is plain that a bean of 39 degrees of plumpness and one of 40 will vary little within one class of size, and therefore taking types from each order which occurs between 10 degrees and 100 is sufficient to classify a bean according to its plumpness and size. Any bean of less than 40° of plumpness and of class III or IV is poor in quality and any bean of over 40° and in class I or II is approaching more nearly to the ideal.

While beans outside limits shown in the plate may occur, the writer in several months' experience of inspection of cacao over 22,743 samples has not met with such abnormalities.

## APPLICATION OF FORMULA.

It is not known what is the exact definition of quality in cacao as desired by the merchant, but it is obvious that such factors as freedom from mould, weevil, slatiness and germinated beans form a part of this quality.

For some months the analysis of Gold Coast cacao leaving the ports has been made with regard to these defects.

The writer wishes to show that other factors can be considered and that these will be ascertained by the application of the formula arrived at in an earlier section of this paper.

Four samples of cacao were selected from a bulk as being as uniform as possible except for length of bean and plumpness. These were supposed to be four samples representing the contents of four uniform bags of the types selected.

Sample No. 1. Large plump beans.

2. Small plump beans.

3. Large flat beans.

4. Small flat beans.

These were then measured for length and plumpness according to the method described in the previous section. The results are given in Table VIII below.

## TABLE VIII.

| Samples. | Large Plump. | | Small Plump. | | Large Flat. | | Small Flat. | |
|---|---|---|---|---|---|---|---|---|
| | Length. | Factor. | Length. | Factor. | Length. | Factor. | Length. | Factor. |
| 1 | 24 | 54 | 20 | 72 | 26 | 25 | 20 | 19 |
| 2 | 23 | 61 | 21 | 65 | 25 | 25 | 19 | 24 |
| 3 | 21 | 68 | 20 | 71 | 25 | 30 | 19 | 24 |
| 4 | 23 | 50 | 20 | 56 | 25 | 26 | 20 | 21 |
| 5 | 23 | 56 | 20 | 63 | 25 | 31 | 20 | 25 |
| 6 | 23 | 51 | 20 | 63 | 24 | 32 | 19 | 21 |
| 7 | 20 | 69 | 21 | 61 | 24 | 22 | 20 | 27 |
| 8 | 24 | 60 | 21 | 61 | 26 | 31 | 18 | 14 |
| 9 | 21 | 71 | 20 | 65 | 23 | 29 | 20 | 19 |
| 10 | 25 | 57 | 18 | 60 | 21 | 23 | 20 | 20 |
| 11 | 22 | 57 | 18 | 65 | 24 | 32 | 20 | 25 |
| 12 | 23 | 57 | 20 | 61 | 27 | 24 | 18 | 22 |
| 13 | 23 | 50 | 20 | 56 | 25 | 26 | 20 | 13 |
| 14 | 21 | 65 | 18 | 62 | 24 | 38 | 20 | 19 |
| 15 | 20 | 61 | 20 | 42 | 24 | 37 | 20 | 19 |
| 16 | 22 | 46 | 20 | 56 | 21 | 24 | 19 | 21 |
| 17 | 21 | 61 | 20 | 50 | 24 | 21 | 17 | 23 |
| 18 | 24 | 56 | 19 | 63 | 26 | 30 | 19 | 21 |
| 19 | 23 | 56 | 20 | 63 | 24 | 32 | 19 | 22 |
| 20 | 24 | 43 | 20 | 63 | 25 | 21 | 19 | 26 |
| Total .. | 450 | 1,149 | 396 | 1,218 | 488 | 559 | 386 | 425 |
| Average | 22.5 | 57 | 19.8 | 61 | 24.4 | 28 | 19.3 | 21 |

*N.B.*—The factors are reckoned to the nearest whole number.

It will be seen from inspection of these results that the average size of the small types placed them in Class III and the large beans in Class II. The average plumpness of the flat beans was 21–28 and that of the plump beans from 57–61%

The samples were then examined according to the method obtaining at the ports when it was seen that the flat types averaged 100% good whereas the small plump beans showed 12% defects and the large plump 4%. See Table below.

## TABLE IX.

### Small Flat Beans.

| Mouldy. | Germ. | Slaty. | Weev. | Defect. | Slaty. | All Other Defects. | Good. |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | 100 |

### Small Plump Beans.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 12 | — | — | — | — | — | 12 | 88 |

### Large Plump Beans.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | — | — | — | — | — | 4 | 96 |

### Large Flat Beans.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | 100 |

From this analysis a merchant in England receiving a report on the defects of this cacao would undoubtedly choose the small flat or large flat beans instead of the plump types and receive a consignment which would certainly not give him as marketable a product as if he had received an account of the class and plumpness.

To illustrate further, one may take an extreme case of two consignments of 100% good beans one of which was of class IV and plumpness 20, and the other apparently similar but of class I and plumpness 60. The resulting price of the two consignments would differ considerably and in a glut of cacao it is conceivable that the former consignment might not find a market. Since cacao is frequently bought by inspection of break, size and plumpness rather than internal defects which are not usually considered except in extreme cases, it appears that a statement of length-class and plumpness might be usefully included in any system of inspection designed to inform a merchant buying cacao at a distance from the production centres.

The system whereby inspection is based on internal defects is due to the operation of food laws and the suggestion of quality is one which the merchant might himself employ with benefit to his consignees.

PAPER No. XII.

# INDICATIONS OF EXISTING CORRELATION BETWEEN THE RAINFALL AND THE NUMBER OF PODS HARVESTED AT ABURI AND ASUANSI.

By C. L. SKIDMORE.

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It is extremely doubtful whether, in the Tropics, any one factor has such a dominating yet limiting effect, not only on the establishment and subsequent success, but also on the yield of a particular crop, as that of rainfall, and, whereas the varying effects of other environmental and meteorologic conditions must of necessity be recognised, yet at the same time, owing to the almost entire elimination of temperature as a limiting factor to plant development, the dependence of crop growth on effective rainfall must assume a very important relationship.

This appears to be especially true with specific regard to the cacao crop, a fact which obtains confirmation not only from the Gold Coast but from other cacao growing areas. Thus, in an extract dealing with the Belgian Congo, (3), it is stated that in certain regions the dry season lasts for five months, and, although the atmosphere is very humid, irrigation is resorted to as " the soil does not always contain sufficient reserves of water to support the cacao trees in a normal state of vegetation, especially at a time when they are bearing fruit."

F. W. Urich (4) states that in San Thomé " The prevailing winds come from the south and south-west. The northern half of the island is dry and the southern very wet. In the leeward or northern district the rainfall is low; from 1915 to 1920 it varied from 24 to 72 inches per annum. In the south the rainfall is between 75 and 100 inches. The dry season is very severe in the leeward district, and there have been as many as 160 days without rain. Were it not for the rivers which flow continually in the numerous valleys, this side of San Thomé would be more like a desert than a district in which cacao can grow."

The effect of rainfall on the cacao crop is also well marked in Ceylon where owing to the north-east and south-west monsoons each blowing for half the year respectively, a period of six months elapses between the main crops on the east and west sides of the Island, and there is a similar lag in the incidence of the minor crop.

Referring to the Gold Coast, G. G. Auchinleck and C. H. Knowles (1) have remarked that for all stations a close parallelism exists (which they hold is clearly a question of cause and effect) between the monthly distribution of the cacao crop and that of the rainfall six months previously.

It is with this parallelism that this paper is concerned, and, whilst the writer is aware that the number of years dealt with form an inadequate period for a study on statistical lines, it is to be hoped that the tentative findings put forward, based though they are on a very imperfect and preliminary method, may prove of some help in that they have pointed to the necessity for certain lines of work in the future which are essential for the elucidation of this very complex problem.

## PHYSIOGRAPHICAL NOTES.

The experimental plot of cacao at Aburi, situated at a high elevation some twenty miles inland, experiences considerable soil wash and, at night, a heavy condensation of moisture due no doubt to this high elevation and its proximity to the sea. This condensation (although not always recorded by a rain-gauge) when considered in conjunction with the position of the plot on the southern side of the hill must have a large environmental effect. It may be noted that the yields here are the highest for the Colony

Asuansi is fourteen miles distant from the sea at a much lower elevation and on the edge of the fringing forest.

At both Stations the mean yearly rainfall is in close agreement although the distribution at Asuansi is slightly more uniform (with a mean annual figure of 49.11 inches) than at Aburi (with a mean annual figure of 47.28 inches).

## CROP DATA.

The data for this paper are drawn from the records of these Experimental Stations. Only yields of Amelonado cacao have been taken into account and each Station has been considered separately. Trees on both Stations are spaced at 15′ x 15′ and the following Table summarises part of the relevant information.

Records are not available for Aburi prior to 1910.

TABLE I.

| Station. | Altitude in feet. | Date of Planting. | Period Reviewed. | No. of Years. | Age of trees at commencement of Period. | Acreage of Plot. |
|---|---|---|---|---|---|---|
| Aburi | 1,450 | 1891–93 | 1910–26 | 17 | 17–19 years | 3.23 from 1910 to 1922 reduced to 2.64 from 1922–26. |
| Asuansi | 330 | 1908–11 | 1914–27 | 14 | 3–6 years. | 10. |

The number of pods harvested per acre represents both diseased and healthy pods which have reached maturity and has been used throughout because not only is it a direct and readily comprehended measure of the productivity of the tree, but also because, for the period considered, any other standard would be open to serious criticism. It has been felt, therefore, that a review of the existing records of these figures might best be relied on for the purpose in view.

The calendar month is plainly of limited importance as a time unit in treating with the physiological responses of plants, but, owing to the lack of uniformity of the harvesting operations for the period reviewed, this wide grouping has had perforce to be adopted.

## RAINFALL DATA.

The crude data used for the years concerned are the rainfall in inches as registered at twenty-four hour intervals in a standard rain gauge openly exposed.

Owing to the lack of knowledge concerning effective rainfall on cacao areas, the summation of daily rainfall into mean monthly totals has been adopted throughout. This is open to criticism as each division of time is treated as independent in effect, and any correlation existing between monthly falls of rain has moreover not been considered.

## EFFECT OF TOTAL RAINFALL ON THE NUMBER OF PODS HARVESTED PER YEAR.

The total rainfall and the number of pods harvested for each year are shewn in Table 2.

## TABLE 2.

| Aburi. | | | Asuansi. | | |
|---|---|---|---|---|---|
| *Year.* | *No. of pods harvested per acre.* | *Annual rainfall in inches.* | *Year.* | *No. of pods harvested per acre.* | *Annual rainfall in inches.* |
| 1913 | 18,028 | 58.11 | 1916 | 16,722 | 47.62 |
| 1911 | 17,190 | 39.77 | 1918 | 16,551 | 41.78 |
| 1918 | 16,501 | 42.24 | 1919 | 13,881 | 41.28 |
| 1916 | 15,822 | 49.66 | 1917 | 13,817 | 74.17 |
| 1914 | 15,752 | 40.05 | 1921 | 13,275 | 47.69 |
| 1912 | 14,599 | 33.40 | 1922 | 10,863 | 54.18 |
| 1926 | 13,955 | 47.75 | .....Line of average yield ..... | | |
| .....Line of average yield ..... | | | 1923 | 9,670 | 55.72 |
| 1921 | 13,238 | 50.83 | 1926 | 9,099 | 43.92 |
| 1919 | 13,002 | 34.54 | 1924 | 8,944 | 48.38 |
| 1910 | 12,388 | 42.67 | 1927 | 8,696 | 39.22 |
| 1922 | 11,836 | 51.39 | 1920 | 8,401 | 47.31 |
| 1923 | 11,755 | 43.14 | 1914 | 7,522 | 41.76 |
| 1917 | 11,620 | 73.16 | 1915 | 7,127 | 52.68 |
| 1924 | 11,309 | 54.14 | 1925 | 6,742 | 52.04 |
| 1915 | 11,289 | 49.65 | | | |
| 1925 | 10,506 | 57.22 | *Average*.....10,807. | | |
| 1920 | 8,291 | 36.40 | | | |
| *Average*.....13,361. | | | | | |

The years are here arranged in descending order of yield. It is patent, however, that the total annual rainfall figures shew no such tendency to arrange themselves in any regular order. On the contrary, the figures, far from following any seeming trend, vary quite indiscriminately—giving no evidence of any correlation between the yield and the total rainfall. If, then, any correlation exists, it must be sought within shorter periods.

## TABLE 3.

| | Aburi. | | Asuansi. | |
|---|---|---|---|---|
| Month. | Mean monthly rainfall. | Mean monthly number of pods picked. | Mean monthly rainfall. | Mean monthly number of pods picked. |
| January .. | 0.92 | 557 | 1.19 | 684 |
| February .. | 1.95 | 64 | 2.43 | 105 |
| March .. .. | 3.68 | 46 | 3.84 | 130 |
| April .. .. | 4.90 | 212 | 4.95 | 351 |
| May .. .. | 6.12 | 353 | 7.33 | 668 |
| June .. .. | 8.09 | 256 | 8.97 | 557 |
| July .. .. | 4.11 | 163 | 3.82 | 290 |
| August .. .. | 2.27 | 581 | 2.13 | 220 |
| September .. | 3.77 | 1,738 | 3.26 | 650 |
| October .. | 4.70 | 3,149 | 4.79 | 1,924 |
| November .. | 4.71 | 3,378 | 3.77 | 3,362 |
| December .. | 2.06 | 2,863 | 2.63 | 1,866 |
| Total .. | 47.28 | 13,361 | 49.11 | 10,807 |

## EXAMINATION OF DATA.

The mean monthly rainfall in inches is calculated for each period, and the mean monthly number of pods harvested also worked out on an acreage basis.

These monthly averages recorded above in Table 3 have been treated as two separate pairs of dependent variables, and correlation coefficients have been worked out for them by the product moment method, using the formula :

$$nr_{12}s_1 s_2 = S(xy)$$

where r is an estimate of the correlation .

By rotating the mean monthly rainfall variables and keeping the crop figures fixed, twelve values of r are obtained for each station giving the relationship between the crop in any month and the rainfall in the same month, one month earlier, two months earlier, etc. These values are given below in Table 4.

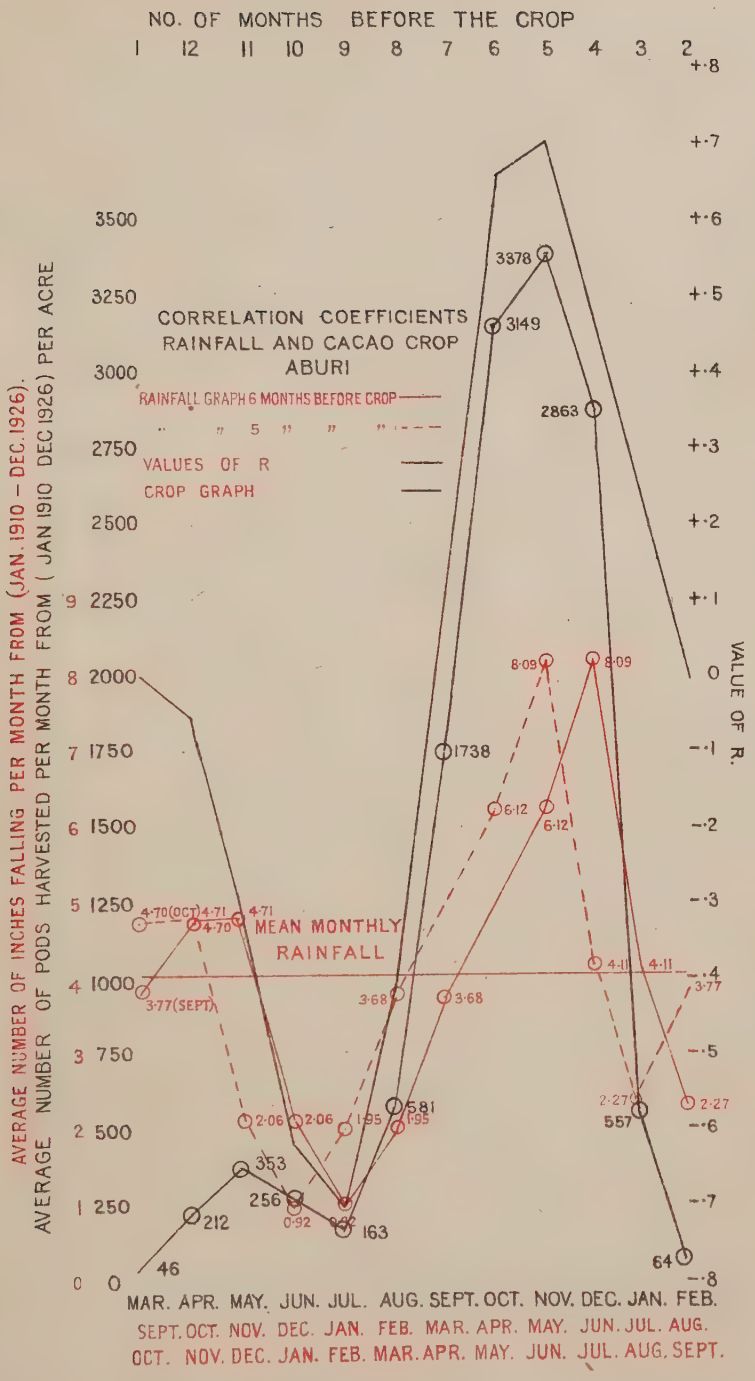
TABLE 4.

| Gross correlation between the monthly crop and the monthly rainfall of. | Aburi. | Asuansi. |
|---|---|---|
| The same month .. .. .. | —.0527 | —.0224 |
| One month before .. .. .. | —.0018 | +.0412 |
| Two months before .. .. .. | —.0172 | +.0955 |
| Three „ „ | +.2065 | —.2741 |
| Four „ „ | +.4456 | +.1302 |
| Five „ „ | **+.7105** | **+.7556** |
| Six „ „ | **+.6599** | **+.7927** |
| Seven „ „ | +.1262 | +.3902 |
| Eight „ „ | —.4129 | —.1218 |
| Nine „ „ | **—.7092** | —.5340 |
| Ten „ „ | —.6240 | —.6347 |
| Eleven „ „ | —.3311 | —.2315 |
| Twelve „ „ | —.0527 | —.0224 |

1. Correlations which would not have been exceeded by chance more than once in fifty trials (P = 2%) have been regarded as significant, and are in heavy type in the Table. Fisher's (2) Tables have been used for this.

Two graphs are appended for these Stations showing the average monthly distribution of the rainfall in inches, the average monthly distribution of the number of pods harvested, and the values of for the crop in any month with the rainfall for different preceding months.

Plate XXXVI




Survey H. Q. Accra, 1929.

## OBSERVATIONS.

From these values of r it is seen that highly significant correlation exists at both Stations between the crop and the rain falling five and six months before. Significant negative values of r are also obtained but are purely figure sequels due to the rotation of one variable. Bearing in mind the fact that the monthly figures are mean values and that the numbers of pairs of observations in each case is therefore twelve, these coefficients are of a definitely high order.

It is interesting to note the general rise and fall of the values of r, indicating that whilst the rainfall five and six months before has a very important effect upon the ensuing crop, the importance of this effect diminishes as the crop nears and attains maturity. At the same time, it is not improbable that the rainfall seven months before also has an effect which is, however, masked by the coarse grouping employed.

Inspection of the two graphs suggests that, in both cases, a better fit with the rainfall curves would be obtained by treating the major and the mid crops as separate entities, or, preferably, by taking finer subdivisions of each.

Moreover, there are, from these graphs, reasons to believe that the mid crop is associated with the rainfall for a longer period before than is the major crop. This is very marked at Asuansi with the younger trees. Although no evidence has been forthcoming on the subject it would be justifiable to suggest that in view of this the mid-season crop takes longer to reach maturity than the main crop.

## SUMMARY AND CONCLUSIONS.

1. The limiting effect of rainfall on the ensuing cacao crop has been illustrated by reference to the Belgian Congo, San Thomé and Ceylon.

2. The absence of knowledge concerning effective rainfall and lesser limiting factors has been noted, and the necessity for narrower periods of harvesting has been pointed out.

3. For Amelonado cacao at Aburi and Asuansi no correlation exists between the total annual rainfall inches and the total annual number of pods harvested.

4. Evidence has been offered of a highly significant correlation exisiting at Aburi and Asuansi between the crop in any month with the rainfall five and six months previously.

A thorough investigation of this relationship and the consequent definition of ' critical periods ' may conceivably be of more than mere commercial interest for prediction purposes. It is possible that the better knowledge thus acquired may be of direct agronomic significance both in its future possible application to irrigation, and in its more immediate assistance for the prescription of seasonal cultural methods.

In conclusion, the author wishes to acknowledge his indebtedness to those officers of the Department of Agriculture who have, by their records, made this cursory review possible.

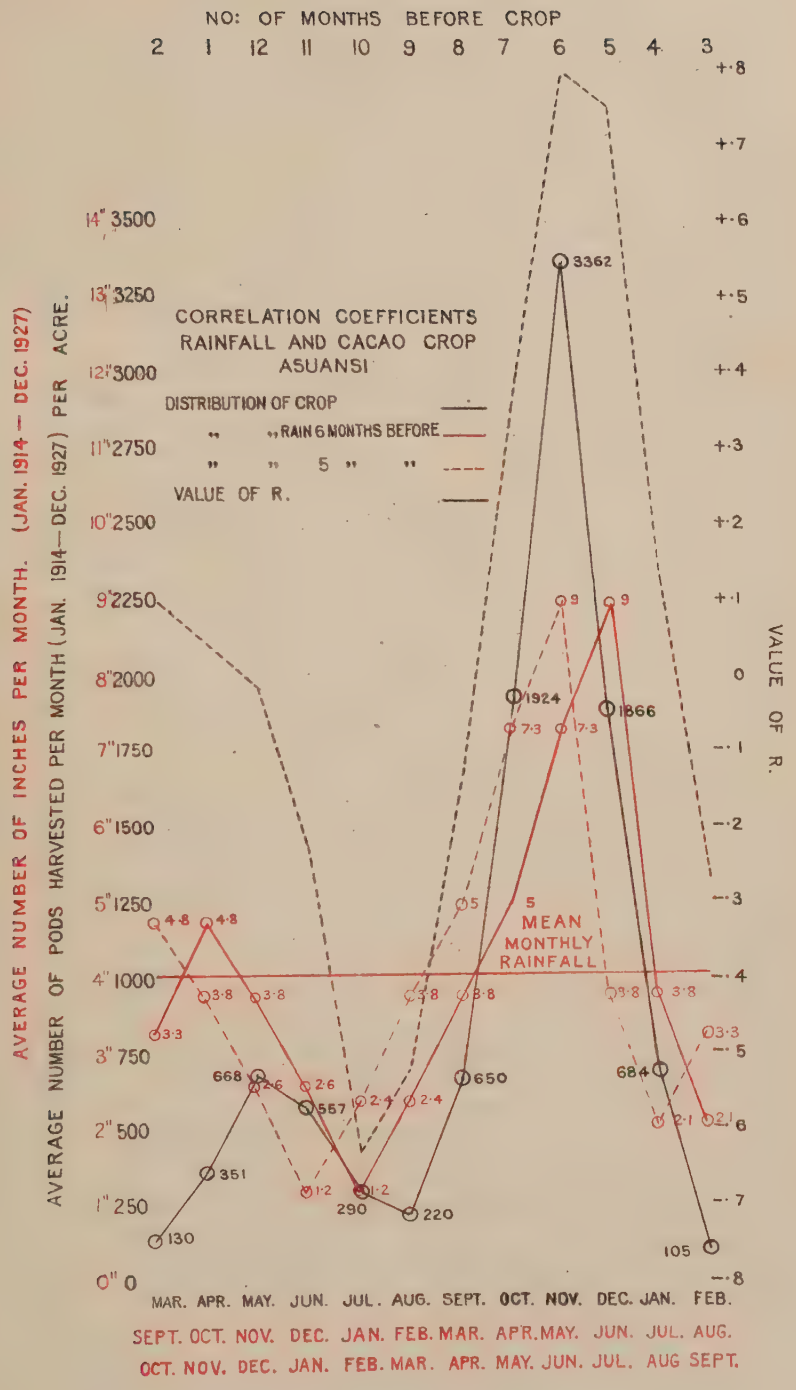
*Literature Cited :*

1 Auchinleck, G. G. and Knowles, C. H. " Yields of Cacao on Experiment Stations " Bulletin No. 4. Department of Agriculture, Gold Coast. 1926.

2. Fisher, R. A. " Statistical Methods for Research Workers " 1925.

3. Ministere des Colonies, " Manuel Pratique de la Culture du Caféier et du Cacaoyer au Congo Belge." 1908.

4. Urich, F. W. " San Thomé Cacao Industry " Tropical Agriculture Vol. V., No. 2. 1928.


NO: OF MONTHS BEFORE CROP
2 1 12 11 10 9 8 7 6 5 4 3
AVERAGE NUMBER OF INCHES PER MONTH. (JAN. 1914 — DEC. 1927)
AVERAGE NUMBER OF PODS HARVESTED PER MONTH (JAN. 1914—DEC. 1927) PER ACRE.
VALUE OF R.
CORRELATION COEFFICIENTS
RAINFALL AND CACAO CROP
ASUANSI
DISTRIBUTION OF CROP
" " RAIN 6 MONTHS BEFORE
" " 5 " "
VALUE OF R.
MEAN MONTHLY RAINFALL
MAR. APR. MAY. JUN. JUL. AUG. SEPT. OCT. NOV. DEC. JAN. FEB.
SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUN. JUL. AUG.
OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY. JUN. JUL. AUG SEPT.

Survey H. Q. Accra, 1929.

## PAPER No. XIII.

# MEASUREMENT OF RATE OF DEVELOPMENT OF CACAO PODS.

*(The investigations dealt with in this paper were conducted by T. Hunter, of the Department of Agriculture, Gold Coast, and H. G. Poynter and I. E. Monu of the Department of Agriculture, Nigeria. The paper has been prepared by H. B. Waters.)*

From April to September, 1925, a cacao tree at Kumasi was photographed twice a week, with the object of recording the growth rate of a cacao pod. The original intention was for this series to form a basis for a cinematograph film to show a cacao pod evolving from a flower and gradually expanding and increasing in size to full development. The photographs were taken under the direction of Mr. T. Hunter at the request of Messrs. Cadbury and Co., Ltd., to whom we are indebted for permission to make use of these photographs.

## DESCRIPTION OF TREE AND ENVIRONMENTAL CONDITIONS.

The variety of the cacao tree was Forastero Amelonado, which is the common type in the Gold Coast. The tree was situated on high ground at about 30 feet above the level of a stream 200 feet away from it. It was 11–12 years of age. The rainfall during the period of pod growth (4th March to 15th September) was above the average in most of the months, as inspection of the following records shows :—

RAINFALL AT KUMASI—INCHES.

| Year. | March. | April. | May. | June. | July. | August. | Sept. |
|---|---|---|---|---|---|---|---|
| 1925 .. .. | 8.79 | 4.67 | 8.09 | 9.52 | 7.25 | 6.48 | 4.66 |
| 1907–28 .. (Average 22 years). | 5.46 | 6.22 | 6.59 | 8.60 | 5.40 | 3.07 | 7.19 |

## DETERMINATION OF MEASUREMENTS.

The length and diameter of the image of the pod on each photograph were determined by measurement. Each set of measurements was corrected according to the scale of each photograph, which was ascertained by noting the distance between well

defined points on the trunk of the tree. Differences in scale were small, as the camera had been placed in almost the same position on each occasion. The pod was known to be approximately 7" long at maturity, so 17.2 cms in length was taken as a basis from which to calculate the actual lengths and diameters from the measurements made on the photographs.

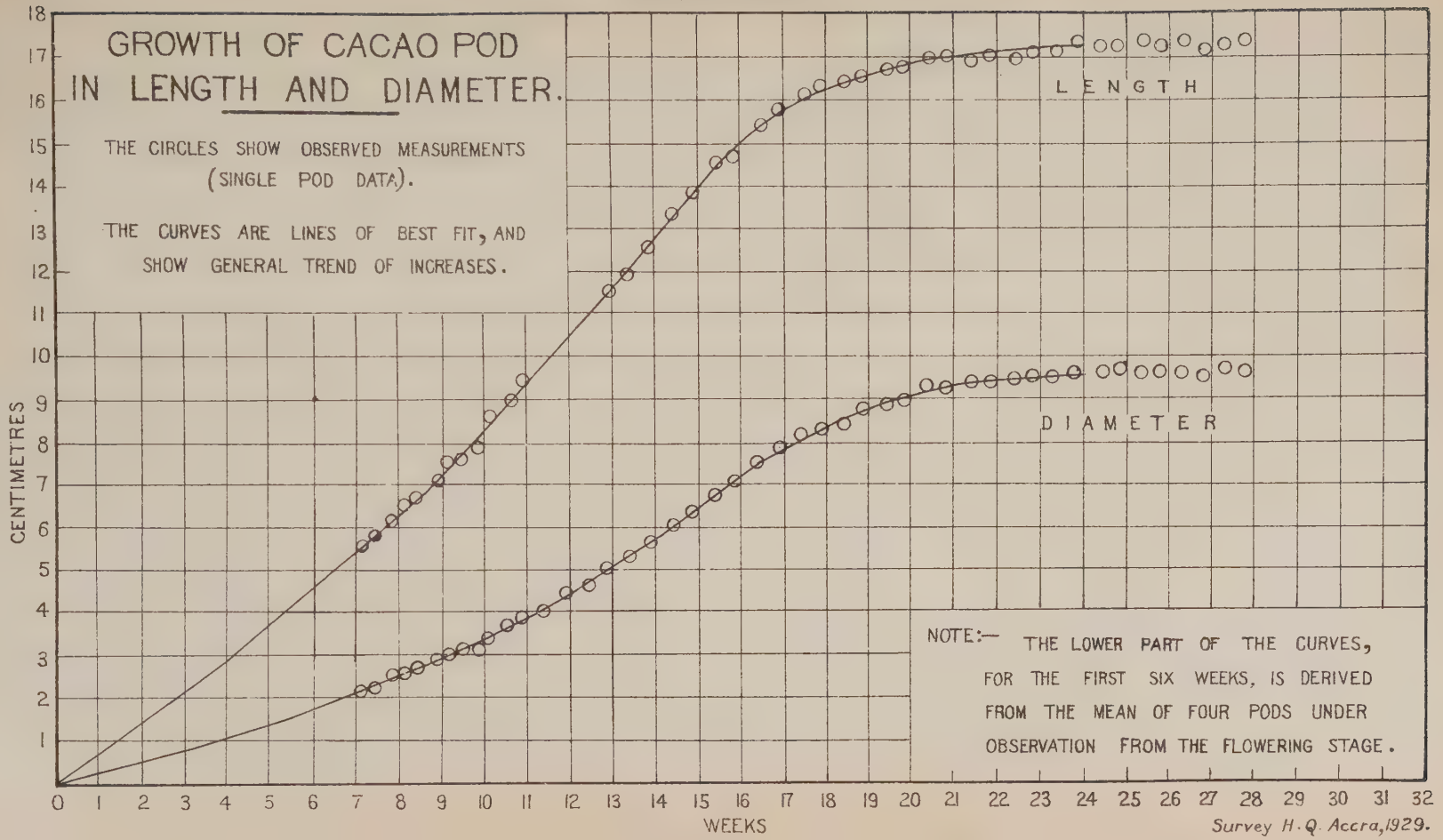
## GROWTH OF CACAO POD IN LENGTH AND DIAMETER.

The actual measurements of length and diameter for a single pod are shown by circles on graph No. XXXVIII. Through these circles have been drawn lines of "best fit," thus showing the general trend of the increases. Daily variations occurred, due to weather conditions, water-shortage, or slight unavoidable inaccuracies in measurement. In this paper, however, we are more concerned with the general rate of increase. The measurements for length and diameter at intervals of a week throughout the pod's life can be obtained by readings on the lines of best fit in graph No. XXXVIII; by this method the following figures were obtained :—

| Age in weeks. | Length. | Diameter. | Ratio (Length to Diameter). | Volume observed (Calculated from Length and Diameter). |
|---|---|---|---|---|
| | m.m. | m.m. | | c.c. |
| 0 | 0 | 0 | — | — |
| 1 | 7 | 2.5 | 2.80 | .02 |
| 2 | 14 | 5 | 2.80 | .16 |
| 3 | 21 | 8 | 2.62 | .6 |
| 4 | 29 | 11 | 2.64 | 1.6 |
| 5 | 37 | 14 | 2.64 | 3 |
| 6 | 45 | 17 | 2.65 | 6 |
| 7 | 54 | 21 | 2.57 | 11 |
| 8 | 63 | 25 | 2.52 | 18 |
| 9 | 73 | 29 | 2.52 | 28 |
| 10 | 83 | 34 | 2.44 | 43 |
| 11 | 94 | 39 | 2.41 | 64 |
| 12 | 105 | 44 | 2.39 | 91 |
| 13 | 116 | 50 | 2.32 | 130 |
| 14 | 128 | 57 | 2.25 | 187 |
| 15 | 140 | 64 | 2.19 | 258 |
| 16 | 151 | 72 | 2.10 | 351 |
| 17 | 158 | 79 | 2.00 | 442 |
| 18 | 163 | 84 | 1.94 | 516 |
| 19 | 166 | 88 | 1.89 | 577 |
| 20 | 168 | 91 | 1.85 | 624 |
| 21 | 170 | 93 | 1.83 | 659 |
| 22 | 171 | 94 | 1.82 | 678 |
| 23 | 172 | 95 | 1.81 | 696 |
| 24 | 172 | 96 | 1.79 | 710 |

(From 22 weeks onwards the figures are of doubtful accuracy as variations in relative humidity mask the effect of inherent growth increase in size).

PLATE XXXVIII


GROWTH OF CACAO POD
IN LENGTH AND DIAMETER.
THE CIRCLES SHOW OBSERVED MEASUREMENTS
(SINGLE POD DATA).
THE CURVES ARE LINES OF BEST FIT, AND
SHOW GENERAL TREND OF INCREASES.
LENGTH
DIAMETER
NOTE:— THE LOWER PART OF THE CURVES,
FOR THE FIRST SIX WEEKS, IS DERIVED
FROM THE MEAN OF FOUR PODS UNDER
OBSERVATION FROM THE FLOWERING STAGE.
CENTIMETRES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
WEEKS
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Survey H.Q. Accra, 1929.

Column 2 shows that growth in length began at the rate of 7 m.m. per week, increased fairly steadily to a maximum rate of 12 m.m. per week at fourteen weeks, and then declined with increasing rapidity until growth practically ceased at the end of the twenty-third week. Column 3 shows that growth in diameter began at the rate of approximately 2½ m.m. per week, increased to a maximum rate of 8 m.m. per week at 15½ weeks, and then declined until growth practically ceased at the end of the 24th week. Column 4 shows that the pod was 2½ times as long as broad at an age of 8½ weeks and gradually became more ovoid until it was only 1.8 times as long as broad after 23 weeks growth.

The figures given for volumes in column 5 will be justified later, but at this stage it will be useful to tabulate some of the information given.

NUMBER OF WEEKS FROM FLOWERING STAGE.

| *To.* | *From flower.* |
|---|---|
| Half final length .. .. .. .. | 10.3 weeks. |
| 3½ inches in length .. .. .. .. | 10.5 ,, |
| Half final diameter .. .. .. .. | 12.7 ,, |
| Maximum rate of increase in length .. | 14.0 ,, |
| Maximum rate of increase in diameter .. | 15.5 ,, |
| Maximum rate of increase in volume .. | 16.0 ,, |
| Half final volume .. .. .. .. | 16.1 ,, |

## VARIATION IN SIZE AND DURATION OF LIFE.

It must be remembered that the curves and figures given are for a single pod, which happened to be one of the earliest pods to be set in the year. The pod took 28 weeks to mature. Growth in volume increased to a maximum rate of 92 c.c. per week at the end of 16 weeks and declined gradually until maturity was reached at the end of 28 weeks. It is interesting to compare this with the growth rate of pods at Ibadan, Nigeria : this is given in the following table :—

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Locality. | Date of Flower. | No. of pods. | Period of time from flower to maximum rate of growth and ½ maximum volume. | Maximum rate of increases in volume. | Final volume of pod. | Period of time from flower to mature pod. |
| | | | Weeks. | c.c. per week. | c.c. | Weeks. |
| Kumasi .. | 4–3–25 | 1 | 16 | 92 | 710 | 28 |
| Ibadan .. | 9–8–27 | 15 | 11½ | 92 | 473 | 21 |
| Ibadan .. | 25–8–27 | 10 | 13½ | 70 | 355 | 20½ |
| Ibadan .. | 14–10–27 | 5 | 10½ | 57 | 295 | 16 |

It will be seen from columns 4 and 7 that the Kumasi pod took much longer to mature, and that the Ibadan pods matured more quickly later in the season, due no doubt to the effect of the dry atmosphere and lack of rainfall from November onwards during the dry season. It is probable that cacao pods in the Gold Coast vary in size and length of life in a similar manner from month to month throughout the year.

## THEORETICAL RATE OF GROWTH BY VOLUME.

Attention is now drawn to Graph No. XXXVIII A showing the growth rate in volume. The curve in this graph is calculated from the formula,

$$\log \frac{x}{720-x} = 0.21\ (t - 16),$$

where x is the volume in c.c. at t weeks from the time when the volume is $\frac{x}{2}$. In this formula, 720 is the final volume of the pod in c.c., 16 is the number of weeks when the pod was half its final size and had completed half its life and the factor 0.21 is calculated from x and t. This is the ordinary S-shaped, or autocatalytic curve, which has been demonstrated to be the underlying curve of growth for living things.* The volume increased gradually at an increasing rate until, when the rate of growth reached 92 c.c. per week, the pod had attained half its final size. Subsequently the volume continued to increase but with a diminishing rate of growth, until growth ceased in theory at 32 weeks from the flowering stage. Actually the pod was ripe and fit to pick at 28 weeks due to the fact that growth from 22 weeks onwards is complicated by the phenomena of ripening.

## CALCULATING THE VOLUME OF A CACAO POD FROM LENGTH AND DIAMETER.

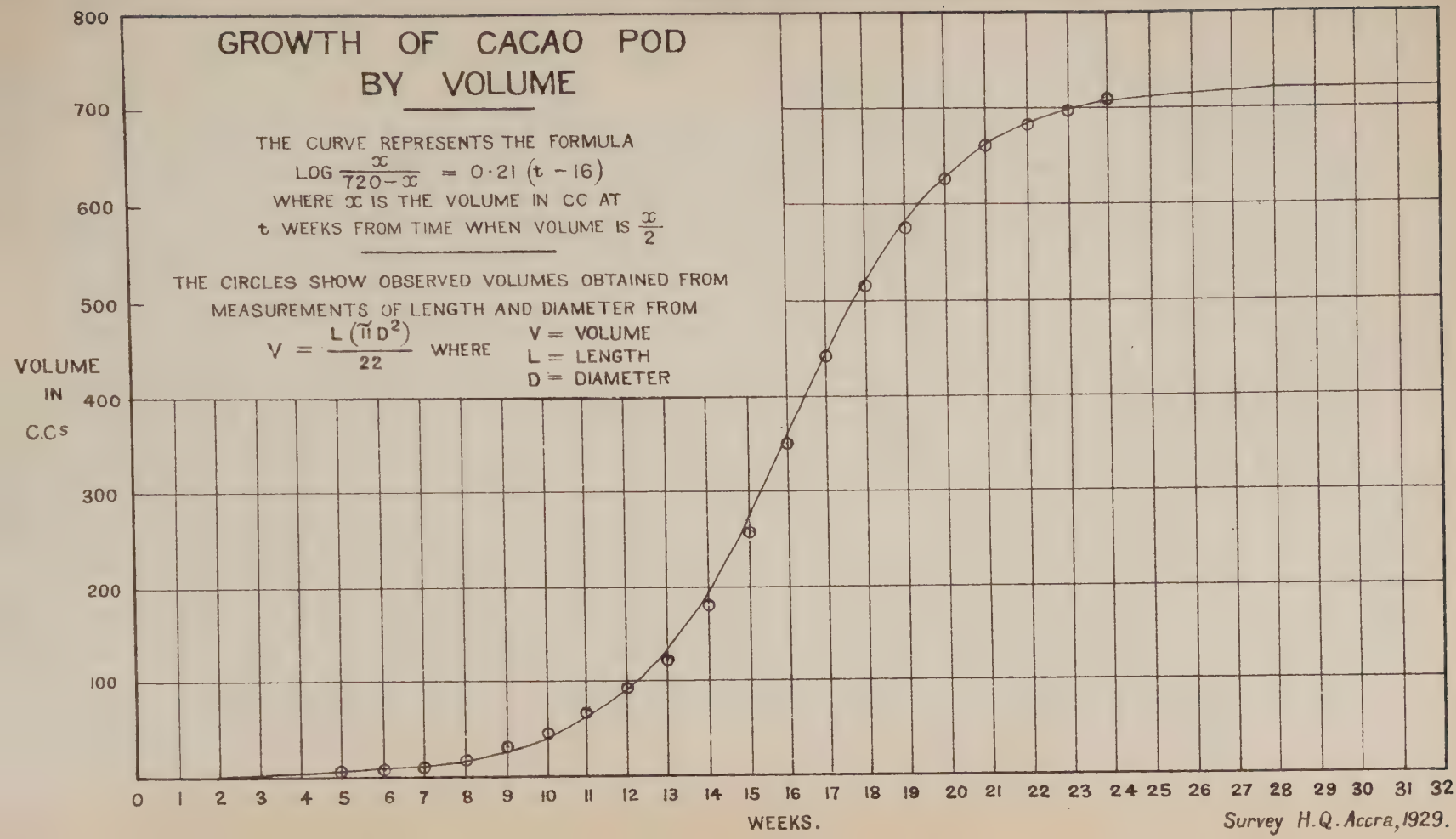
The observed values for volumes were obtained by calculation from the measurements of length and girth. The formula used was :—

$$V = \frac{L\ (\pi D)^2}{22}.$$

where V = Volume of pod
L = Length of pod
D = Diameter of pod.

*Robertson—" The chemical basis of growth and senescence."

PLATE XXXVIII. A.


GROWTH OF CACAO POD BY VOLUME
THE CURVE REPRESENTS THE FORMULA
LOG x/(720−x) = 0·21 (t − 16)
WHERE x IS THE VOLUME IN CC AT t WEEKS FROM TIME WHEN VOLUME IS x/2
THE CIRCLES SHOW OBSERVED VOLUMES OBTAINED FROM MEASUREMENTS OF LENGTH AND DIAMETER FROM
V = L(πD²)/22 WHERE V = VOLUME L = LENGTH D = DIAMETER
VOLUME IN C.Cs
800
700
600
500
400
300
200
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
WEEKS.
Survey H.Q. Accra, 1929.

The validity of this formula rests on the fact that the shape of a pod approximates to that of a prolate spheroid (the formula for which is $\frac{L\ (\pi D)^2)}{6\pi}$ )and that errors introduced by expansion and alteration in shape are balanced by errors due to the relatively decreasing depth of restrictions throughout the pod's life. Its accuracy has been tested in Nigeria by harvesting all the pods from one tree, measuring the length, diameter and volume, and calculating the factor $\frac{L\ (\pi D)^2}{V}$ As all the pods were from the same tree it is not unreasonable to make the assumption that the large pods on the trees were similar to the pods into which the small pods would develop : in other words, a series of pods of increasing size is taken to represent the growth of a single pod. The full results are not published here, bu the following are averages :—

TREE No. 1.

| Length of pod c.m. | 3.4 | 4.7 | 6.1 | 8.2 | 10.8 | 13.1 | 16.0 | Average. |
|---|---|---|---|---|---|---|---|---|
| $\frac{L\ (\pi D)^2}{V}$ | 22.0 | 22.3 | 22.8 | 22.2 | 21.7 | 22.2 | 22.2 | 22.2 |

TREE No. 2.

| Length of pod c.m. | 4.4 | 8.7 | 12.0 | 16.1 | Average. |
|---|---|---|---|---|---|
| $\frac{L\ (\pi D)^2}{V}$ | 22.2 | 21.8 | 22.9 | 22.3 | 22.3 |

There is no apparent underlying variation from small to large pods. Also the deviations are so small that it seems reasonable to assume that the growth of a pod by volume can be calculated from the formula $\frac{L\ (\pi D)^2.}{22}$ The actual denominator to use does not affect the rate of growth, and 22 has been used instead of the 22.2 recorded for Nigerian pods.

In order to demonstrate this point beyond any manner of doubt it would be necessary actually to record volumetric and linear measurements for a growing pod throughout its life. The volume would have to be measured, presumably, by displacement.

## COMPARISON BETWEEN THEORETICAL AND OBSERVED RATE OF GROWTH.

The observed volumes, derived from the measurements of length and girth, and the theoretical volumes, derived from the autocatalytic curve, were as follows :—

| Weeks. | Volume observed. c.c. | Volume theoretical. c.c. |
|---|---|---|
| 0 | — | — |
| 1 | .02 | — |
| 2 | .16 | — |
| 3 | .6 | 1 |
| 4 | 1.6 | 2 |
| 5 | 3 | 4 |
| 6 | 6 | 6 |
| 7 | 11 | 9 |
| 8 | 18 | 15 |
| 9 | 28 | 23 |
| 10 | 43 | 37 |
| 11 | 64 | 59 |
| 12 | 91 | 91 |
| 13 | 130 | 137 |
| 14 | 187 | 198 |
| 15 | 258 | 275 |
| 16 | 351 | 360 |
| 17 | 442 | 445 |
| 18 | 516 | 522 |
| 19 | 577 | 583 |
| 20 | 624 | 629 |
| 21 | 659 | 661 |
| 22 | 678 | 683 |
| 23 | 696 | 697 |
| 24 | 710 | 705 |
| 25 | — | 711 |
| 26 | — | 714 |
| 27 | — | 716 |
| 28 | — | 718 |
| 29 | — | 719 |
| 30 | — | — |
| 31 | — | — |
| 32 | — | 720 |

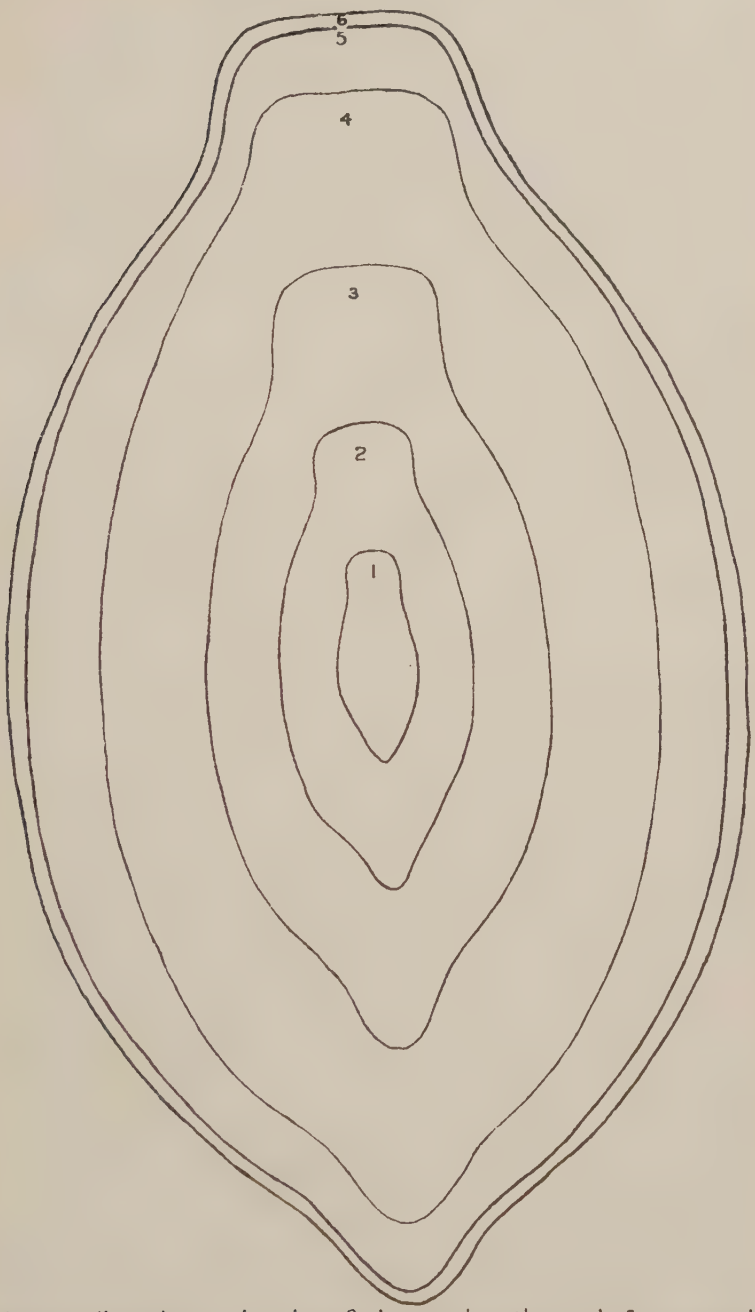
The observed volumes agree well with the calculated values, although a better agreement could have been obtained by appropriate statistical methods.

Growth rate curves have usually been recorded by weight, e.g., the case of the cucumber cited by Robertson. A test was therefore carried out with pods of different sizes and it was found that the specific gravity remained practically constant at 0.98 for green pods but fell to 0.80 for fully ripe pods. The curve for volume therefore represents the curve for weight, until the higher bend is reached, where ripening sets in.

# PLATE. XXXVIII. B.

## MONTHLY GROWTH OF CACAO POD

From single pod data. Actual size.
Kumasi — March to August 1925.




The smallest outline shows the size of the pod at the end of one month's growth from the flowering stage, and remaining outlines show the size of the pod at ages of from two to six months successively.

The two outside outlines do not represent the thickness of the shell: the outside line shows the size at the end of six months' growth and the line next to it shows the size at the end of five months' growth.

*Survey H.Q. Accra, 1929.*

## ESTIMATING THE CACAO CROP BY POD DATA.

The interest in this paper is two-fold. In the first place actual measurements of pods in the young stage on a farm give a basis on which to make an estimate of the yield in dry cacao to be expected from that farm, and of the time when the crop is likely to be ripe. There are various difficulties in getting a reliable estimate by this method due to shedding of young pods, varying incidence of disease, varying number of pods to give one lb. of dried cacao, and so on. Each of these factors is dependent on conditions and can be estimated separately ; papers XII, XIV and XV in this Year-Book deal with different aspects of this subject. By recording the estimated and actual yields each year for a number of years it should be possible to improve on the estimation each year. If this were done on a limited number of farms scattered over the Gold Coast and representative of the cacao area, these records should form the foundation of a very accurate estimate of the seasonal crop in the Gold Coast. Actually a very good estimate can be made on available data, but it is clear that every additional basis for estimation constitutes a further step in the direction of accuracy in forecasting the cacao crop.

## FURTHER GROWTH-RATE STUDIES INDICATED.

The second interest in this paper lies in the fact that the cacao pod increases in size in accordance with a well-known law of growth. This opens up a number of secondary problems for investigation. Use could be made of self-recording apparatus, similar to that now employed for measuring growing apples at the Dominion Experimental Farm, Summerland, in Canada ; so delicate is its adjustment that day and night growth is accurately recorded. In particular it is desirable to record the growth rate, final size and duration of life, of pods growing under different conditions, to investigate the effect of rainfall and water-supply, and to study variations in pods maturing at different times throughout the year.

## SUMMARY.

1. Measurements of length and diameter are recorded for a cacao pod throughout its life from flower to mature pod.

2. A method for calculating from these data the rate of growth in volume is justified and applied.

3. Further studies are suggested, (i) to improve crop prospect data and (ii) to increase our knowledge of the growing cacao pod.

## PAPER No. XIV.

# FLUCTUATIONS IN THE RATIO BETWEEN NUMBER OF PODS AND RESULTANT WEIGHT OF CACAO.

By H. K. HEWISON.

One noticeable feature of the published summaries of the annual yields of cacao is the very considerable variation which exists from year to year in the average number of pods required to produce a given weight of dry cacao. In the records for the Amelonado plot at Aburi, for example, the average number of pods per pound of dry cacao ranges, over a period of years, from 11.1 to 18.8—a variation of 69.36 per cent. Similar records relating to the Asuansi Amelonado, plot V, shew a variation of 87.64 per cent.

On the surface, there is apparently no relationship between such variation in pod value and the increase or decrease in the total amount of marketable produce, a fact that has been commented upon by the compilers of Bulletin No. 4 (1926) in which publication, Summary " D " and Table (2) *et seq.* evidence may be obtained.

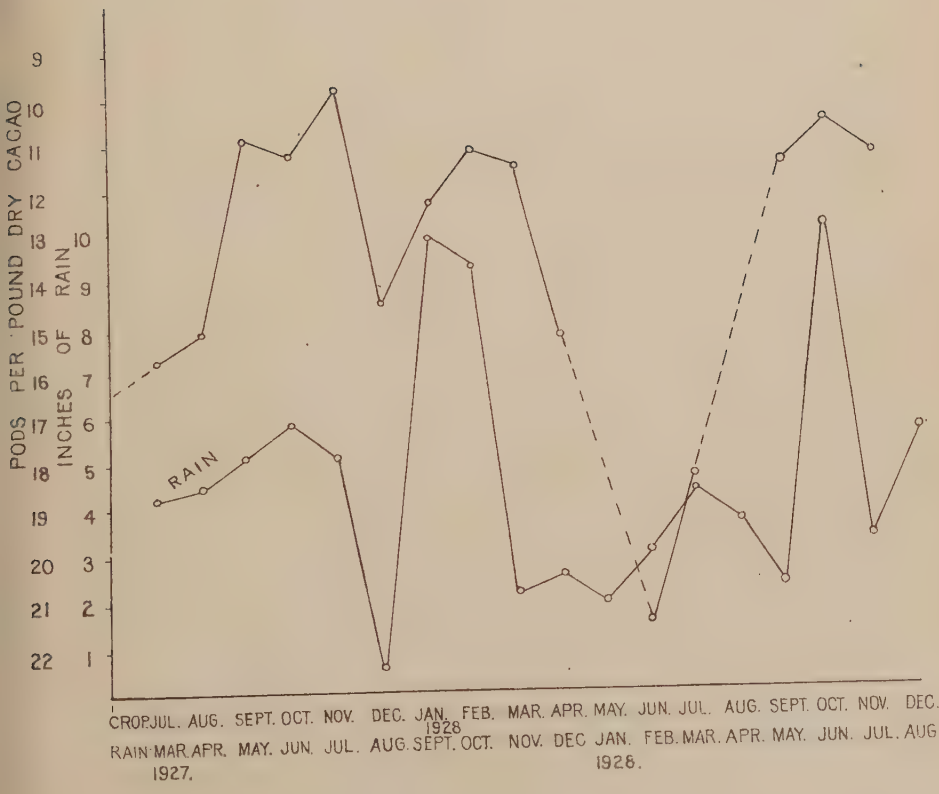
Any attempt to explain this variation in general terms of a good or bad year for production fails on the score that a good yield (suggesting conditions approaching an optimum) is quite often built up of a high average number of pods per pound of dry cacao, whilst conversely, an inferior yield from pods of high value (i.e., low average number per pound of cacao) is equally frequent. It is also noteworthy that pod value cannot be associated with the actual numbers of pods produced, for high value is not necessarily offset by numerical inferiority nor is a low pod value compensated for by a greatly increased production of fruit.

It is in connection with this seeming anomaly, which the writer considers will ultimately prove capable of explanation on the hypothesis of the Carbohydrate-Nitrogen ratio advanced by Kraus and Kraybill (1918), that evidence is sought regarding the dry cacao value of pods from individual pickings.

The figures that exist at Kpeve, if reviewed *per annum*, shew just as great diversity of pod value as those of any station. But if considered per month of per picking there appears to be evidence of a seasonal fluctuation in value. During the period of the early crop, despite considerable unsteadiness, there is a definite tendency for pod values to be low, but during the months of September, October and November the values are consistently high—tending to fall off through December and reach a low ebb toward the following mid-year.

Plate XXXIX

CURVES OF
POD VALUES AND RAINFALL 1927 1928.
KPEVE INVESTIGATIONAL
STATION.




Survey H. Q. Accra, 1929.

In the following Table are set out the pods per pound of dry cacao recorded for each month of the years 1922, '23, '26, '27, '28.

PODS PER POUND OF DRY CACAO.

| Month. | 1922 | 1923 | 1926 | 1927 | 1928 | Average. |
|---|---|---|---|---|---|---|
| January | .. No record | 12.45 | 12.77 | 17.01 | 12.30 | 13.63 |
| February | .. No record | 12.10 | No crop | 15.28 | 11.17 | 12.85 |
| March .. | .. No record | 11.82 | 15.90 | No crop | 11.56 | 13.09 |
| April .. | .. 11.36 | 12.28 | No crop | 17.51 | 15.22 | 14.09 |
| May .. | .. 13.03 | 14.76 | 17.75 | No crop | No crop | 15.18 |
| June .. | .. 14.63 | 12.75 | No crop | No crop | 21.53 | 16.30 |
| July .. | .. No crop | No crop | 16.50 | 15.61 | 18.33 | 16.81 |
| August .. | .. 10.83 | 11.57 | No crop | 15.07 | No crop | 12.39 |
| September | .. 11.30 | 11.37 | 11.36 | 10.83 | 11.56 | 11.28 |
| October | .. 11.41 | 11.38 | 9.70 | 11.35 | 10.60 | 10.89 |
| November | .. 12.63 | 10.76 | 11.40 | 9.76 | 11.33 | 11.17 |
| December | .. 11.55 | 13.14 | 13.57 | 14.43 | 9.88 | 12.51 |

Although the figures for 1925 support the hypothesis of seasonal fluctuation, they and the returns for 1924 have been rendered abnormal through long breaks between pickings, and as the inclusion of abnormalities would serve no purpose those years are omitted.

The figures tabulated above certainly suggest a tendency toward seasonal fluctuation. Unfortunately, the absence of the requisite meteorological data prior to March, 1927, prevents the examination of the entire range of values with regard to their relationship with rainfall which is probably the factor of predominating influence. It is interesting to note, however, that over the period for which rainfall figures are available the superimposition of the curve of pod values for each month on that of the rainfall four months earlier clearly indicates the existence of correlation. The accompanying graph No. XXXIX supporting this relates to the crop months since July, 1927, and the monthly rainfall from the previous March.

As will be seen, the general relationship indicated by the graph with the sustained influence of the heavier rains of September and October, 1927, is sufficiently satisfactory to warrant further investigation. Should confirmatory evidence be forthcoming, the establishment of the existence of correlation between rainfall and pod value should throw considerable light on some of the problems of the cacao crop.

PAPER No. XV.

# VARIATIONS IN THE PERCENTAGES OF CACAO CROP LOST THROUGH POD DISEASES.

By H. K. HEWISON.

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In view of the publication of data and considered statements concerning losses and damage through pod disease obtaining in areas of cacao under native control (Economic Significance of Cacao Pod Diseases; Department of Agriculture, Bulletin No. 6, Dade, 1927) it may not be without interest to consider figures emanating from a source more nearly comparable with a farm than are the majority of Government Stations.

Kpeve was chosen originally for the specific purpose of establishing cacao, and, save a very small portion of the stand, was planted-up in 1913–1914 with Amelonado at four metres (roughly 13′ x 13′).

The area lies in a valley, is well sheltered laterally by contour and vegetation, and is drained by a local stream which winds at considerable length through the plantation. No definite scheme of shade exists but over a good portion of the area oil palms standing singly or in groups overshadow the crop. In the main, the trees stand in fairly deep, medium clay, which appears very retentive of moisture, and overlying the clay is a deep layer of rich humus. Excepting those adjacent to oil palms, the trees may be said to be in excellent condition, symmetrical and having good lateral branch development.

In an analysis of results from eleven reapings scrutinised in the neighbourhood of Anyinam, Dade (ibid.) gives an average figure of four per cent. as the extent of an owner's actual loss of crop attributable to discards occasioned by disease. Discards and " pods badly damaged by disease " combined (which may probably be taken as the standard of exclusion on Stations) average to about eighteen per cent. whilst seventy per cent. of the total pods picked are infected by disease to a greater or lesser extent.

It must be borne in mind, however, that, for the purpose of subsequent comparison, allowance should be made for the fact that the foregoing figures are calculated on a total which includes a category that does not (or certainly should not) assume any appreciable dimensions in controlled Station pickings.

In excluding the six or seven per cent. of "Unripe Sound Pods," therefore, the figures for the infection and losses should be increased slightly.

In the following Table are set out the percentage of disease-infected pods of the monthly pickings from April, 1926.

## TABLE I.

PERCENTAGE OF TOTAL PODS COLLECTED FOUND TO BE INFECTED.

| Month of Picking. | 1926. | 1927. | 1928. |
|---|---|---|---|
| January .. .. .. .. | ? | 48.74 | 16.65 |
| February .. .. .. .. | ? | 32.82 | 7.41 |
| March .. .. .. .. | ? | — | 11.18 |
| April .. .. .. .. | — | 52.38 | 22.19 |
| May .. .. .. .. | 79.43 | — | — |
| June .. .. .. .. | — | — | 28.93 |
| July .. .. .. .. | 50.13 | 48.55 | 11.85 |
| August .. .. .. .. | — | 3.39 | — |
| September .. .. .. | 28.01 | 18.41 | 10.68 |
| October .. .. .. .. | 30.79 | 14.55 | 7.33 |
| November .. .. .. | 26.31 | 21.08 | 17.26 |
| December .. .. .. .. | 25.91 | 13.39 | 25.51 |
| Average .. .. .. | 40.01 | 28.15 | 15.89 |

The range is wide, extending as it does from 79.43 in May, 1926 to 3.39 in August, 1927, and there is a very appreciable difference between the average percentage pod infection for the three years themselves.

In the absence of the requisite meteorological data, it is not possible to array these figures in relation to night and day fluctuations in relative humidity, and, as they stand, there appears to be no particular regularity in increase or decrease of infection, nor do they appear capable of association with any general seasonal features

The existence of months in which no picking occurred is unfortunate, for the amount of infection recorded for the following month must inevitably be affected thereby. Such is almost certain to be the case in respect of May and July, 1926, and April and July, 1927.

On the other hand, the variations from month to month even where a regular series of pickings is made are very considerable, and the increases recorded for January and September, 1927 over the amount shewn for the months immediately preceding them are anything but insignificant.

The proportion of disease-infected pods found to be rendered useless according to Departmental standards of selection and rejection is shewn by expressing the loss as a percentage of the infections, and appears in the following Table.

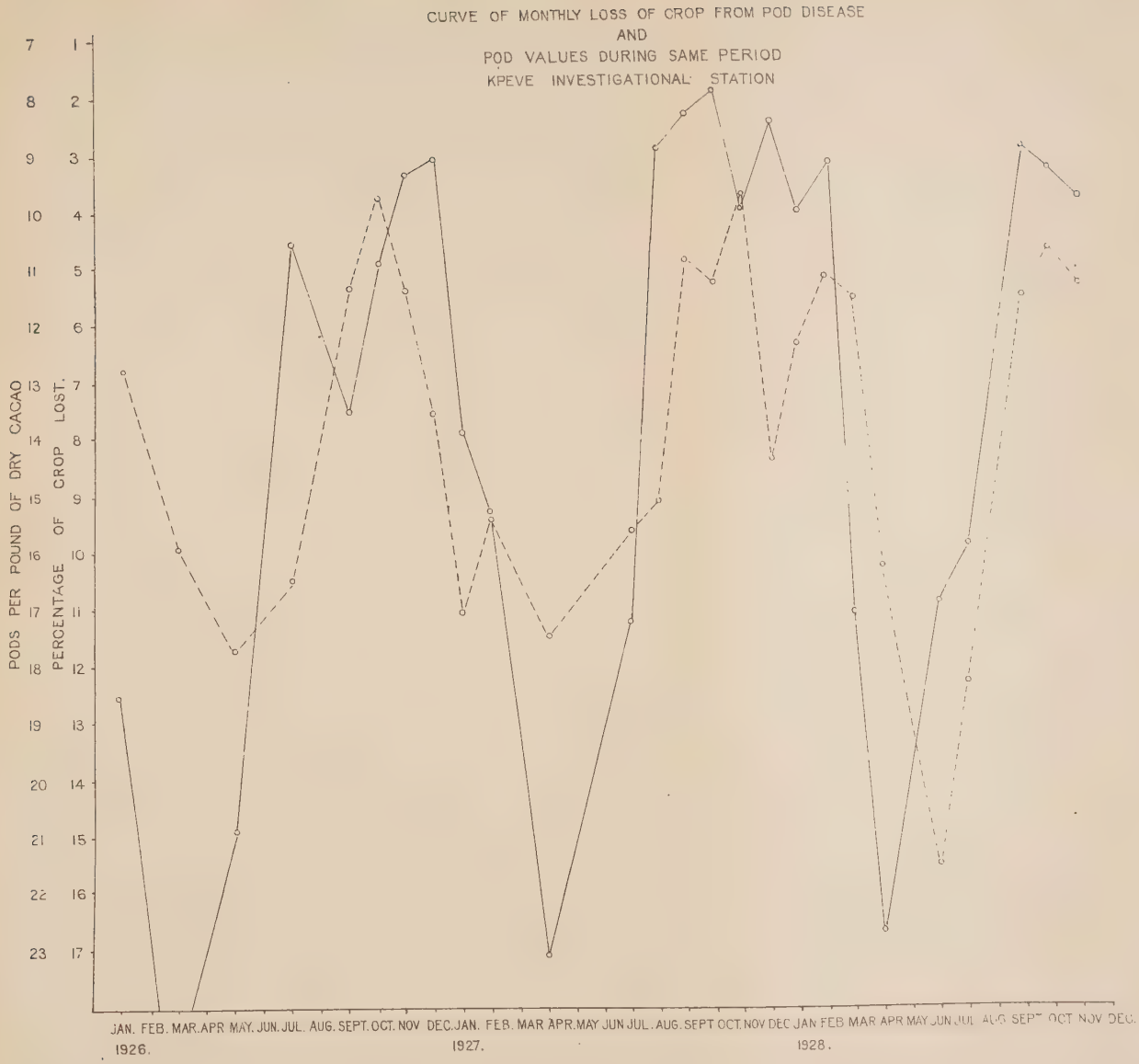
## TABLE II

### Percentage of Infected Pods rendered useless

| Month of Picking. | 1926. | 1927. | 1928. |
|---|---|---|---|
| January .. .. .. .. | ? | 16.27 | 24.07 |
| February .. .. .. .. | ? | 28.13 | 42.15 |
| March .. .. .. .. | ? | — | 96.66 |
| April .. .. .. .. | — | 32.44 | 72.84 |
| May .. .. .. .. | 18.71 | — | — |
| June .. .. .. .. | — | — | 37.61 |
| July .. .. .. .. | 9.14 | 23.05 | 83.26 |
| August .. .. .. .. | — | 84.39 | — |
| September .. .. .. | 26.50 | 12.31 | 27.23 |
| October .. .. .. .. | 16.04 | 12.61 | 43.75 |
| November .. .. .. | 12.59 | 18.54 | 22.81 |
| December .. .. .. .. | 11.88 | 18.10 | 12.36 |
| Average .. .. .. | 15.81 | 27.32 | 46.27 |

As will be observed, the fluctuations are many and very irregular and, when taken in conjunction with the figures of Table I, it is evident that the numerical extent of infection is no criterion of the extent of damage in terms of useless pods. In July, 1926, and in January, 1927, when the infected pods amounted to somewhere in the region of fifty per cent. of those picked, only 9.14% and 16.27% of the infected pods were sufficiently bad to warrant discarding. Yet, on the other hand in August, 1927 and again in March, 1928, with infected pods only amounting to 3.39% and 11.18% of the collections, 84.39% of the former and 96.66% of the latter were useless.

Plate XL


CURVE OF MONTHLY LOSS OF CROP FROM POD DISEASE
AND
POD VALUES DURING SAME PERIOD
KPEVE INVESTIGATIONAL STATION
PODS PER POUND OF DRY CACAO
PERCENTAGE OF CROP LOST.
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
JAN. FEB. MAR. APR MAY. JUN. JUL. AUG. SEPT. OCT. NOV DEC. JAN. FEB. MAR APR. MAY JUN JUL. AUG. SEPT OCT. NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEPT OCT NOV DEC.
1926.
1927.
1928.

Survey H. Q. Accra. 1929.

When extracting the figures for the latter end of 1926 and the beginning of 1927, the possibility of a seasonal variation in intensity of infection suggested itself, but, as will be seen, such cannot be supported by evidence. There is, however, a rather interesting similarity in the yearly rise and fall in the percentage loss of potential crop over the three years under review. This figure (the potential crop) is derived by adding to the actual dry cacao obtained in any one month the *pro rata* value of the useless pods and then extracting the percentage of the possible crop which those useless pods represent.

TABLE III.

PERCENTAGE LOSS OF POTENTIAL CROP DUE TO USELESS PODS.

| Month of picking. | 1926. | 1927. | 1928. |
|---|---|---|---|
| January .. .. .. .. | 12.63 | 7.94 | 4.00 |
| February .. .. .. .. | — | 9.24 | 3.15 |
| March .. .. .. .. | 53.18 | — | 11.09 |
| April .. .. .. .. | — | 16.90 | 16.62 |
| May .. .. .. .. | 14.87 | — | — |
| June .. .. .. .. | — | — | 10.88 |
| July .. .. .. .. | 4.57 | 11.20 | 9.85 |
| August .. .. .. .. | — | 2.89 | — |
| September .. .. .. | 7.42 | 2.26 | 2.90 |
| October .. .. .. .. | 4.94 | 1.83 | 3.21 |
| November .. .. .. | 3.31 | 3.90 | 3.79 |
| December .. .. .. .. | 3.08 | 2.42 | 3.15 |
| Average .. .. .. | 13.00 | 6.51 | 6.86 |

Before proceeding to a consideration of the question of seasonal variation in loss, it may be noted that the average loss in each year is considerably higher than that found by Dade (loc. cit.) in native-controlled farms, and in the year 1926 is about three times as great.

That the more rigid selection carried out on stations would result in this is only natural, although frequent pickings, leading to many pods being collected in the earlier stages of infection before they are useless, must have a very big influence in the other direction.

Reverting to Table III an inspection of the figures set out therein shews that the percentage loss of potential crop due to useless pods follows a fairly definite seasonal fluctuation which, even in view of the small number of years under consideration, cannot be dismissed as mere coincidence. The point is interesting and one

that warrants investigation, for while the importance of the humidity factor in furthering the progress of the disease is undeniable, the figures suggest that another factor is in operation which, either by dominating the course of the disease subsequent to infection or by masking the effect attributed to humidity, plays a very important part. This would appear to find some measure of support in the total absence of correlation between the percentage of pods infected and those rendered useless (*vide* Tables I and II) and it may not be improbable that the physiological condition of the tree during the period following infection may be largely responsible.

If such is the case, then as a plant will express itself not only in its growth but in its reproduction, and as, therefore, the extent to which a plant endows the seeds it bears will in some measure reflect its vigour, this may be taken, tentatively, as a measure of condition.

On this assumption, the accompanying graph, Plate No. XL plotting as it does the vigour of the trees expressed in pods per pound of dry cacao against the percentage of the potential crop lost by disease, shews, in view of the arbitrary standard used, the existence of a remarkable similarity.

## PAPER No. XVI.

# FURTHER NOTES ON CUSHION CANKER OF CACAO.

By H. A. DADE.

(*Supplementary to "The Relation between Diseased Cushions and the Seasonal Outbreak of 'Black Pod' Disease of Cacao, H. A. Dade, which appeared in the Year-Book* 1927, *to which reference should be made*).

In the cacao season of 1928, with the object of studying the course of the disease, two hundred artificial inoculations were made at Anyinam Field Station, on Site A (Plot 2 of 1926—*see* Bulletin No. 6 of this Department). This is situated in a farm in which cushion canker is common. Half of the infected cushions were dissected at intervals after inoculation. The other half have been left undisturbed for dissection next season when the activity of the fungus is resumed.

So far as could be judged by careful examination healthy cushions bearing healthy pods were selected. A culture of *Phytophthora Faberi* Maub., obtained from a diseased pod, was used. The pods were inoculated at a point half way down their sides by lightly scratching the epidermis and placing a mass of sporangia on the wound.

Plate XLI shows diagrammatically the progress of infection of the cushion in selected cases which are typical of those dissected 16, 20, 46 and 64 days after inoculation of the pods.

(In considering the following notes reference should be made to Paper No. XIX in this Year Book, in which some details of anatomy of the cushion are briefly described).

Invasion of the peduncle, as far as its insertion on the "spur," takes place very early in the history of the pod infection. Sections cut in peduncles showed that fungus enters, and spreads in, the peduncle both in the cortex and in the true medullary rays of the dissected stele. The xylem segments do not appear to be invaded, though they are deeply discoloured in the diseased areas.

Plate XLI is a photomicrograph of part of a section through a peduncle near its insertion on the pod, and shows the structure and the discoloration of the vascular and cortical tissues caused by the fungus.

When the fungus reaches the spur, however, it evidently meets with a distinct check in the cortex, a fact which may be correlated with the perennial nature of the spur. In the vascular strand however infection proceeds without apparent check, still *via* the medullary rays.

Subsequently the cortex of the spur and cushion are usually attacked to some extent, and sometimes the whole of the cortex of the cushion is involved. Occasionally infection spreads to the bark of the main axis (Plate, XLI Nos. 27 and 28) and an active bark canker is formed. This does not seem, however, to be the normal course of events. In all other cases, where spur and cushion only were involved, about two months after the original inoculation the cankered portions dried up, and were cut off from the crest of the cushion tissues by a secondary meristem—a cork cambium. The dried masses of dead tissue were detached from the live bark, from which they eventually fell away. It appears therefore that the majority of direct cortical infections die out at a comparatively early stage, though occasionally the cushion may be destroyed, while the formation, in this direct way, of active cankers of the trunk bark is still more infrequent.

As has been stated, in previous notes, eventual recovery of the trunk bark is usual, though the attack lasts over at least two seasons. During the active attack on the bark a succession of meristems are set up, and are the origin of the fine red lines which form a visible network in the freshly cut diseased tissue. At the end of general invasion, which normally covers only a few square inches of bark, a successful cork cambium is formed, the diseased portion of the bark becomes detached from the healthy tissues, and regeneration begins.

In the vascular strand infection proceeds without check to the insertion of the trace on the main stele. Here hyphæ have been found in sections, and from this region too the fungus has been recovered in culture.

Between the spur and the insertion of the trace the general discoloration of the strand thins out more or less into black lines, in longitudinal sections, or spots in transverse sections.

Sections show that discoloration is due to large vessels, and cells near them, becoming charged with gum and tannins, cause and effect being the same as in the case of discoloration in the tissue in pods and peduncles.

After reaching the insertion of the trace, the discoloration, still in the form of thin black lines, may be traced by dissection into the cambium of the trunk, to a distance of three or four inches below the cushion.

# Plate XLI

Diagram illustrating progress of infection in cushion canker.

Fig. 1 Key.

Figs. 2–9. Infection of cushion from pod, 16 days after inoculation of pod

" 10–13. Ditto, 20 days after inoculation.

" 14–21. Ditto, 46 " " "

" 22–28. Ditto, 64 " " "

" 29–35. Infection of healthy cushion and pod from previously infected bark.

Survey H Q. Accra, 1929.

Hyphæ have not yet been found beyond the insertion of the peduncular strand, and it is possible that further discoloration may be due to a distant toxic effect. Cells on both sides of the cambium are involved. Only the first two or three layers of cells on the xylem side are affected—i.e., those not yet fully differentiated—while on the phloem side several layers are killed. The medullary rays are more deeply affected on each side. In good cases the radial depth of the affected tissue may reach a quarter of an inch just below the cushion, the depth thinning out downwards. The width of the affected tissue in these cases is variable, but may be up to an inch.

The inoculaton of the pods was made on the 8th August. Dissections made after the 11th October showed no further advance, the last being made in December. The activity of the fungus has therefore been temporarily arrested due no doubt to seasonal physiological changes in the host.

We find, during the growth and maturation of the pod, that canker spreads rapidly into cushions from previous bark infections. On the other hand after the pod has been destroyed by disease, the cushion and surrounding bark exhibit some measure of resistance to attack, resistance which is often successful, and results in recovery. These facts appear to indicate a change in the physiology of the host tissue related to the nutritional conditions connected with presence or absence of the growing fruit. The same general, or related, changes probably are responsible for the checking of fungus activity when infection has reached the cambium and the renewed activity in the bark in the beginning of the following season.

The presence of the fungus in the damaged cambial region below the cushion has not been demonstrated up to the present. There is, however, very strong circumstantial evidence for its presence.

The cells and cell contents exhibit phenomena identical with those found in tissue in which hyphæ have been found, i.e., formation of tyloses in vessels, of gum and tannin in vessels and neighbouring cells, increased deposit of calcium oxalate crystals in cells of the phloem and rays, and discoloration.

In tissues of the cushion in which the fungus has been definitely found, only a few hyphæ appear in sections, although the whole of the surrounding tissue is affected.

In the previous notes on this subject, the invasion of the cortex from a previous bark infection was shown to take place from below the cushion. The dissections described and illustrated showed the existence, below the cushion, of a large bark canker. The situation of these cankers corresponds with the area in the cambium

affected by infection from the pod. In Plate, XLI Nos. 29 to 35 are diagrams of some of the cases, dissected this season, of resumed activity of the canker and the infection by it of the healthy cushion. It is significant that in all these cases the outer bark below the cushion was quite healthy at the first examination but subsequently became diseased. The pods, resting against this area of the bark, remained healthy, so that infection could hardly have taken place from the outside. The facts therefore all point to infection of the bark, in the second season, from the cambial area in which fungus growth was arrested in the previous year.

The further study of the infected cushions which have been reserved for dissection next year may establish beyond doubt the connection between the deep-seated cambial damage resulting from infection of the main axis from the diseased pod and the bark canker from which the new healthy cushion tissue becomes again infected.

In the meantime circumstantial evidence permits us to assume that the full history of cushion canker is as follows.

From the peduncle of the diseased pod the cortex of the spur and cushion may or may not become infected. If it does a large bark canker and destruction of the cushion may follow at once, but more generally only a part of the cushion cortex is damaged, and recovery ensues. The fungus travels without check through the peduncular trace, mainly *via* the medullary rays, as far as the insertion of the strand on the main stele. From thence it apparently proceeds downwards in the cambial region, and a large shallow plate of tissue, mainly phloem, is involved. Further spread of infection now ceases for the duration of the dry season. In most cases, i.e., where the cushion has not been destroyed, flowering and fruiting proceed normally in the next season. The rapid growth and swelling of the cushion cortex, and renewal of the strand to supply the requirements of the growing pod, results in the covering up of all superficial traces of the old infection. The fungus is now isolated in its deepest outpost in the cambium. It apparently resumes activity by attacking the adjacent bark, advances outwards and in its spread involves the now healthy cushion and eventually the fruit by way of the cortex of the peduncle or perhaps, rarely, by the vascular strand as well (*see* Plate, XLI No. 33).

T.S. part of peduncle, near its insertion on the pod, × 20 d., showing the dissected stele and true medullary rays, and discoloration of both vascular and cortical tissues caused by *Phytophthora Faberi*.

## PAPER No. XVII.

# THE NON-TOXICITY OF THE SECRETIONS OF PHYTOPHTHORA FABERI-MAUBL.

By. J. J. OBENG.

This investigation was undertaken at the suggestion and with the assistance of the Mycologist (Mr. H. A. Dade).

Its object was to discover whether the substances secreted by *P. Faberi* are toxic to cacao tissues.

In black pod disease and in cushion canker large areas of discolored and necrotic tissue are found in which hyphae cannot be demonstrated. This may be due either to disappearance of the fungus from the damaged tissues through the exhaustion of nutritive material or through auto-intoxication, or to the toxic effect of the fungus secretions on host tissues which have not been actually invaded by the fungus.

The experimental method adopted involved the injection of pods with fluid media in which the fungus had been cultivated and from which it was subsequently removed by filtration.

Two media were employed—Dox fluid and dilute corn meal infusion. Lots of about 25ccs. each of these were sterilised in small conical flasks and inoculated with a pure culture of *Phytophthora Faberi* freshly isolated from a diseased pod.

Duplicate flasks of sterile medium were kept for control injections.

After six days incubation the cultures were filtered. Several sets of filtering apparatus were prepared by fitting small glass funnels to 3″ x 1¼″ specimen tubes with cotton wool plugs; two layers of filter paper were placed in the funnels and the top of the funnels covered with filter paper.

The apparatus is illustrated in the sketch Fig. 1.

These pieces of apparatus were sterilised in the hot air oven. Cacao pods were sterilised with mercuric chloride solution in the usual manner and placed in the sterile glass vessels. A hypodermic syringe was sterilised by boiling in water. The paper cover of a filtering apparatus was now removed and the contents of a culture flask poured into a filter. With the least delay the syringe was charged with the filtrate, and cacao pods were inoculated each in several places by plunging the needle through the cortex and sclerenchymatous layer into the placental cavity.

As the needle was withdrawn the inoculum was forced from the syringe, and thus was brought into contact with the placental mucilaginous tissue, vascular tissue and cortical tissue A stainless steel needle was used to prevent the discoloration which the use of ordinary steel entails.

The wounds were in some cases covered with sterile paraffin wax, and in other cases were left uncovered.

Control inoculations were made using medium in which the fungus had not been grown.

After five days the pods were dissected and examined. The wounds had remained sterile, indicating that the method of filtration-sterilisation used was efficient.

In all cases there was no discoloration along the needle track excepting a very superficial brown oxidation change.

There was no difference between the effect in the case of experimental pods and the control pods.

(In some cases the heated paraffin wax caused slight superficial necrosis of the epiderms, but this is of course not significant).

It is therefore concluded that the substances secreted by *P. Faberi* have no toxic action on the tissues of cacao pods.

NON-TOXICITY ---- PHYTOPHTHORA FABERI MAUBL." - OBENG.

TEXT FIGURE.

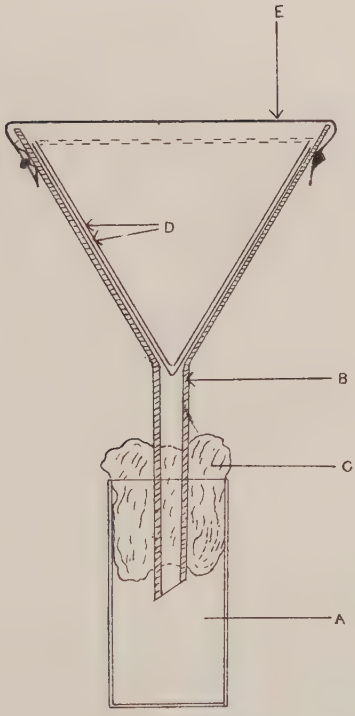



FIG. 1. STERILE FILTRATION APPARATUS.

A - SPECIMEN TUBE.
B - FUNNEL.
C - COTTON WOOL PLUG.
D - DOUBLE FILTER PAPER.
E - PAPER CAP.

*Survey H. Q. Accra 1929.*

PAPER No. XVIII.

# MULCHING TRIAL WITH CACAO ON KUMASI AND ASUANSI EXPERIMENT STATIONS.

## Part I—(Kumasi).

By H. NICHOLAS.

The experiment on which this paper is based was laid down by Mr. T. Hunter, who is responsible for collecting all the data used.

The cacao used was of the Amelonado variety, with trees planted out 1908–1910. In 1919 a 1-acre plot in about the middle of the 11-acre block was demarcated as the plot to be mulched, and the yields from it recorded. A similar 1-acre plot alongside was demarcated as the control or unmulched plot, and its yields were also recorded. The plots selected were as even as possible and under similar Para rubber shade. The yields from these plots up to the end of 1927 are given in the accompanying table.

### MULCH.

The mulching material used was practically any green vegetation available—weeds, grasses and soft bush from any convenient area, which were allowed to dry out for one day before conveying. Two bundles of mulch, each weighing about 80 lbs., were applied to each tree ; the weight of mulch per acre was therefore about 10 tons 15 cwts. A maximum distance of a quarter mile was allowed for conveying the mulch, and on this basis the average cost worked out at £1 2s. 6d. per acre, which over the period of nine years for which comparative yields are available gives a total cost of £10 2s. 6d.

### PROFIT.

The revenue from each plot obtained by the sale of dry cacao was worked out for the nine years on the basis of the average price per load obtaining in each year. The difference in revenue in favour of the mulched plot was almost exactly £20. Subtracting from this the cost of mulching (i.e., £20 minus £10 2s. 6d.), a net profit of £9 17s. 6d. per acre is obtained.

## DEDUCTIONS.

Facts to be learned from the Table of figures and the accompanying graph are as follows :—

(*a*) At the commencement of the experiment the plots were almost equal in yield.

(*b*) Both plots have decreased in yield.

(*c*) The decrease in yield has been much more marked in the case of the unmulched plot, and the divergence is becoming greater.

(*d*) The greater part of the fluctuations in yield from year to year in the two plots is similar, implying a similarity in effect of external factors upon yield and this is of importance in determining the significance of the data by statistical methods.

## STATISTICAL ANALYSIS OF DATA.

The problem is to determine the significance of the apparent greater decrease in yield of the unmulched plot over the mulched plot ; or in other words, to determine if the apparent tendency of mulching to maintain yield is significant.

The problem was worked out by Fisher's method for determining the significance of the mean of the differences.

The statistics are :—

$$S(x-\bar{x})^2 = \tfrac{1}{12}n^1(n^{12}-1) = \tfrac{1}{12}9(81-1) = 60$$

$$b = \frac{S(y(x-\bar{x}))}{S(x-\bar{x})^2} = \frac{7895-5(1231)}{60} = 29.$$

The unmulched plot therefore appears to be decreasing in yield more rapidly than the mulched plot at the rate of 29 lbs. dry cacao per annum. Or, the mulched plot appears to be more nearly maintaining its yield than the unmulched plot at the rate of 29 lbs. dry cacao per annum.

To estimate the standard error of b :—

$$S(y-Y)^2 = S(y^2) - n^1\bar{y}^2 - b^2S(x-\bar{x})^2$$

$$= 276515 - 167940 - 50460 = 58115$$

$$s^2 = \frac{1}{n'-2}\,S(y-Y)^2 = \frac{58115}{7} = 8302$$

$$\text{Standard error} = \sqrt{s^2/S(x-\bar{x})^2} = \sqrt{\frac{8302}{60}} = \sqrt{138.4} = 11.76$$

$$t = \frac{29}{11.76} = 2.466$$

n = degrees of freedom = 9-2 = 7

Therefore P is between .02 and .05

The result is therefore judged significant, and we can say that mulching has tended to maintain the yield.

TABLE I.

| Year. | Yield dry cacao in lbs. | | Difference. |
|---|---|---|---|
| | (*a*) Mulched. | (*b*) Unmulched. | = (*a*) — (*b*). |
| 1919 .. .. | 811 | 835 | –24 |
| 1920 .. .. | 953 | 904 | 49 |
| 1921 .. .. | 947 | 721 | 226 |
| 1922 .. .. | 702 | 642 | 60 |
| 1923 .. .. | 669 | 637 | 32 |
| 1924 .. .. | 913 | 646 | 267 |
| 1925 .. .. | 792 | 694 | 98 |
| 1926 .. .. | 700 | 448 | 252 |
| 1927 .. .. | 698 | 427 | 271 |
| Totals .. | 7,185 | 5,954 | 1,231 |
| Means .. | 798.33 | 661.55 | 136.66 |

## INFLUENCE OF MULCHING ON SIZE OF POD.

It is probable that one of the most important effects of mulching would be to increase the size of the pods, or in other words, the amount of dried cacao produced by each pod. To investigate this the weight of dried cacao produced by each plot in each year from 100 pods was calculated, and the result is shown in Table II, columns (*c*) and (*d*).

From these figures it will be seen that after the fourth year of mulching the difference was appreciable, and has tended to increase.

The data were analysed statistically by the same method as in the paragraph above.

The statistics are :—

$$S(x-\bar{x})^2=60$$

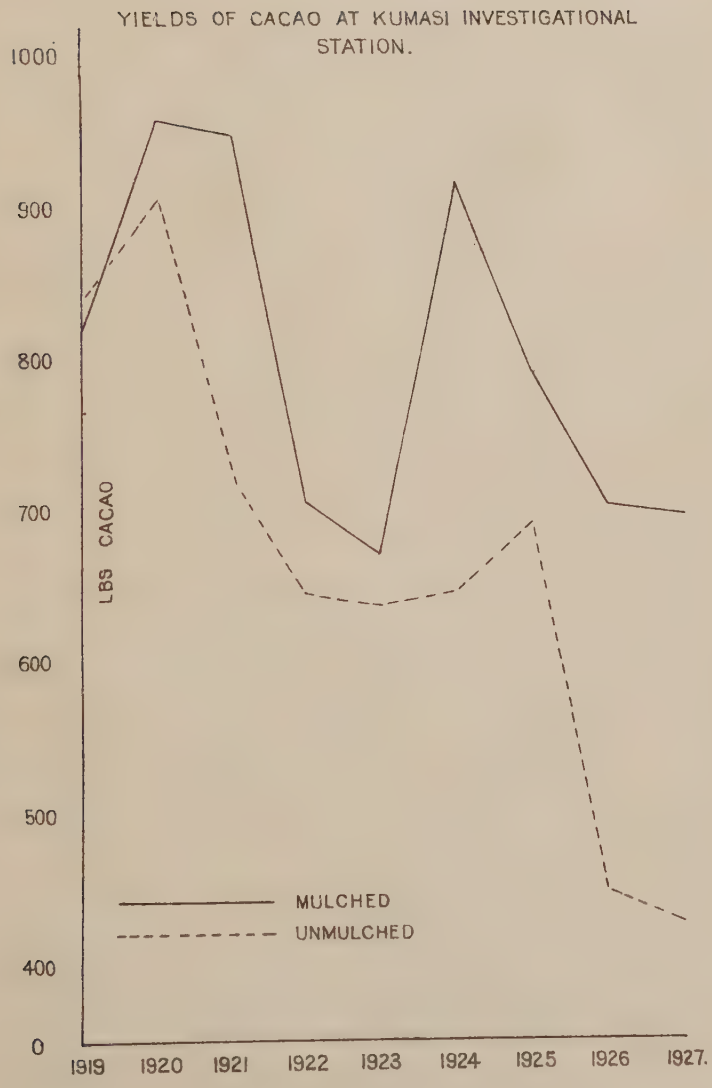
$$b=\frac{S(y(x-\bar{x}))}{S(x-\bar{x})^2}=\frac{21.93-14.45}{60}=(.12466)$$

Therefore the weight of dried cacao produced by the mulched plot appears to be gaining on that from the unmulched plot at the rate of very nearly $\frac{1}{8}$ lb. per 100 pods per annum.

## TABLE 11

| Year. | Mulched. | | (*c*) | Unmulched. | | (*d*) | |
|---|---|---|---|---|---|---|---|
| | Pods fermented. | lbs. dried cacao. | lbs. dried cacao per 100 pods. | Pods fermented. | lbs. dried cacao. | lbs. dried cacao per 100 pods. | Difference = (*c*) — (*d*). |
| 1919 .. .. | 10,106 | 811 | 8.03 | 10,395 | 835 | 8.03 | 0 |
| 1920 .. .. | 11,322 | 953 | 8.41 | 10,751 | 904 | 8.41 | 0 |
| 1921 .. .. | 10,659 | 947 | 8.88 | 8,111 | 721 | 8.88 | 0 |
| 1922 .. .. | 8,494 | 702 | 8.28 | 7,773 | 642 | 8.26 | .02 |
| 1923 .. .. | 8,130 | 669 | 8.22 | 7,861 | 637 | 8.10 | .12 |
| 1924 .. .. | 10,772 | 913 | 8.47 | 7,769 | 646 | 8.31 | .16 |
| 1925 .. .. | 8,495 | 792 | 9.32 | 8,156 | 694 | 8.51 | .81 |
| 1926 .. .. | 6,961 | 700 | 10.05 | 5,179 | 448 | 8.65 | 1.40 |
| 1927 .. .. | 8,204 | 698 | 8.51 | 5,248 | 427 | 8.13 | .38 |
| Total .. .. | .. | .. | 78.17 | .. | .. | 75.28 | 2.89 |
| Means .. .. | .. | .. | 8.68 | .. | .. | 8.36 | .32 |

Plate XLIII




Survey H. Q. Accra, 1929.

To estimate the standard error of b :—

$S(y-Y)^2 = 2.8009 - .9280 - .9325 = 0.9404$

$s^2 = \frac{.9469}{7} = .13434$

Standard error $= \sqrt{\frac{.13527}{60}} = \sqrt{.002239} = .0473263$

$t = \frac{.12466}{.0474763} = 2.634$

$n = 7$

Therefore P is between .02 and .05.

The result is therefore judged significant, and we can say that mulching has tended to increase the size of the pods. It is noteworthy that the result obtained in this case is more significant than that obtained for the maintenance of yield.

## Part II—(Asuansi).

By W. H. BECKETT.

On Asuansi Experiment Station records of two one-acre plots of Amelonado cacao were kept from 1922 till 1927. The treatment was similar to that on the plots at Kumasi. The records of pods, dry cacao, and dry cacao per 100 pods are given below, together with the differences calculated as for the Kumasi figures.

| Year. | A Pods fermented. | | B lbs. dry cacao. | | C lbs. cacao per 100 pods. | | Difference. | |
|---|---|---|---|---|---|---|---|---|
| | Mulched. | Un-mulched. | Mulched | Un-mulched. | Mulched. | Un-mulched. | b. | c. |
| 1922 | 7,632 | 8,498 | 668 | 730 | 8.76 | 8.58 | —62 | .18 |
| 1923 | 7,554 | 7,572 | 744 | 747 | 9.84 | 9.86 | — 3 | —.02 |
| 1924 | 9,099 | 5,760 | 709 | 535 | 7.80 | 9.30 | 174 | —.50 |
| 1925 | 7,729 | 5,135 | 679 | 470 | 8.78 | 9.15 | 209 | —.37 |
| 1926 | 9,256 | 7,162 | 818 | 605 | 8.83 | 8.44 | 213 | .39 |
| 1927 | 9,451 | 6,194 | 628 | 428 | 6.65 | 6.94 | 200 | —.29 |
| Total | 50,621 | 40,321 | 4,246 | 3,515 | 50.66 | 52.27 | 731 | —.61 |
| Means | 8,437 | 6,720 | 708 | 586 | 8.44 | 8.71 | 122 | —.1 |

The average annual cost of mulching for the six years under trial was £4 10s. an acre; a considerably higher figure that at Kumasi for the same quantity of mulch material. The difference was due to the fact that the material had to be cut at first from areas not specially grown for mulch and also to the longer transport distance.

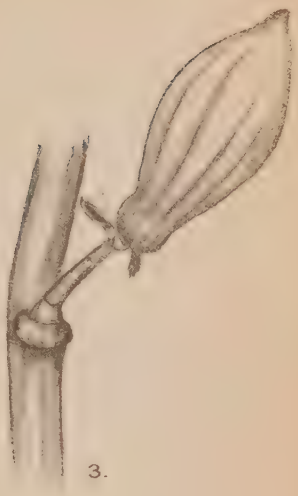
Some differentiation of the tissues on either side of the articulation might be expected. There is however no apparent anatomical difference. At its insertion on the pod the peduncular trace splits into five axial strands which traverse the placenta and supply the seeds. Other strands are distributed into the cortex. If the peduncle is cut immediately above the pod, the stele is found to be dissected, the radial wedges of vascular tissues being divided by true medullary rays (i.e., not vascular rays, but radial extensions of the medulla). Five of these rays, representing the divisions between the five incipient axial strands, are very large. The remainder are much narrower. There is a small medulla. If transverse sections are cut farther up the peduncle, the pith is found to disappear quickly while the medullary rays become greatly reduced in thickness. At and beyond the articulation there is no change in the tissues.

The course of infection of cushions by *P. Faberi*, however, seems to indicate that there is some physiological difference. In all cases the cortex and vascular strand of a diseased pod are completely involved in attack, and are discolored (see Paper XVI). On the proximal side of the articulation, however, infection is to some extent inhibited. The cortex appears to be more resistant than the strand. In latter stages in the history of canker, the cortex is readily attacked, so the early resistance is probably due to some physiological periodicity, either of the fungus, the host, or both. The difference certainly exists, and may be linked with the different morphological significance of the two parts of the axis—*i.e.*, the perennial spur and the annual peduncle.

If the fruit-bearing cushons are to be regarded as branches, we should expect to find that they spring from axillary buds. In the case of trunk cushions on grown trees, it is impossible to trace any such origin, but if we examine branch cushions it is usually very easy to see that such is actually the case In Plate No. XLIV figures 1-4 show examples of first year branch cushions. The leaf scars seen below the cushion, which, in the course of its rapid growth, splits the scar into two halves.

In very young trees with smooth bark, the origin of cushions is sometimes evident, for the leaf scars are in some trees presistent for a few years. In Plate XLIV figures 5-7 show such cases.

In old trees which have been in bearing for some years very numerous cushions are formed, and with the distortion due to twisting of the trunk, and to the increase in size of the cushions, it is not easy to distinguish any kind of regular arrangement. In some types of trees however—those with very long trunks, evenly developed and with comparatively smooth bark, such as are rather common in native farms in the Gold Coast—there are striking indications of a spiral arrangement of the cushions. This is also clearly shown in trees where a quickly grown chupon has replaced the original trunk, which has been destroyed by accidental damage.



L. D. del.

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Figs. 1, 2. Two views of a branch cushion, showing leaf scar forced aside in two halves by expansion of the branch below the cushion. (Pod removed.)

Figs. 3, 4. Origin of cushions in leaf axils on branches. (Pod removed in 4.)

Figs. 5-7. Cushions formed in leaf axils on trunks of young trees. Leaf scars still visible. (Pods removed.)

(ORIGIN AND SPIRAL ARRANGEMENT OF CUSHIONS IN CACAO — DADE.)

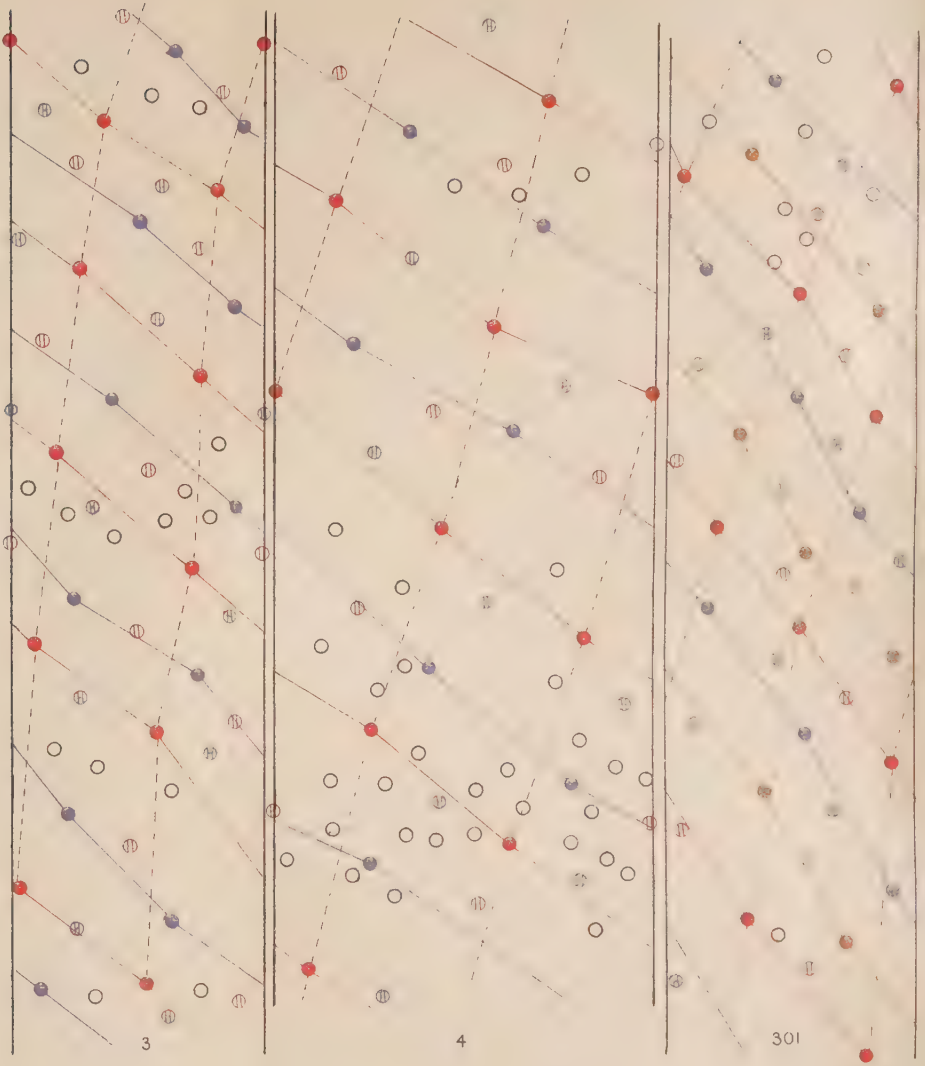


PLATE XLIII. PROJECTIONS OF LOWER PARTS OF TRUNKS OF TREES NOS. 3, 4, AND 301, SHOWING ARRANGEMENT OF CUSHIONS.

Survey H.Q. Accra, 1929.

If we attempt to trace spirals on grown trees we find that there are far too many cushions formed to fit in with the original leaves. The obvious explanation is that while the axillary buds of original leaves may have given rise to cushions, others have been formed from adventitious buds.

If careful plans of the cushions on suitable trees be made and from them flat projections, the whole system becomes more clear. A single series of distinctly placed cushions is first of all selected and may be regarded—arbitrarily—as the series derived from the axillary buds of the actual leaves put out by the young shoot. In some young trees the original leaf scars and the first series of young cushions formed in their axils, may be clearly seen. A set of projections made from Amelonado trees are reproduced in Plate XLIII. In these the arbitrarily chosen original series is marked red and joined with a red line. We are guided, in thus sorting out the series, by the approximate vertical distance between the leaf scars on chupons in which longitudinal growth has ceased.

The broken red lines joining cushions are inserted for the purpose of marking out corresponding quadrilateral areas on the trunk surface which render more distinct the regular arrangement of the secondary and tertiary series. (These lines are not parastichies). It will be seen that the cushion arrangement corresponds with the $\frac{3}{8}$ phyllotaxis of cacao.

Having selected and marked the original series, we find that between the turns of the spiral numerous other cushions are set. If we regard the series first selected as the original one, the remainder of the cushions must have been formed from adventitious buds. But we can see clearly, in many cases, that these intermediate cushions are also arranged in a regular system, with the same radial intervals, and parallel to the first series. In most cases (e.g., trees 3 and 4 Plate XLIII), a secondary series is formed exactly half-way between the turns of the first spiral, and occasionally there are indications of tertiary series between the primary and secondary systems. In other cases two series are formed between the turns of the primary spiral—e.g., tree 301 (a chupon) in Plate XLIII. In Plate XLIII the various series are shown in different colours. Cushions of incomplete series are indicated by black circles.

It is hardly profitable, at this stage, to speculate on the nature of the ideal complete system of cushion formation on the cacao trunk. It is sufficient to assume that a number of potential spirals exist, and that they are developed or suppressed according to the nutritional resources of the trees and to the available area of trunk surface.

In chupons arising as water shoots from the bases of trees longitudinal growth is very rapid, and the leaves are more widely spaced than in the case of seedling axes. The resultant spiral is

therefore more drawn out. This is clearly seen in the tree No. 301, in Plate XLIII, the trunk of which is derived from a water shoot which replaced the original trunk.

In seedling stems the phyllotaxis of the leaves is by no means so easy to trace as in the case of water-shoots. Leaves are formed much more irregularly, more twisting of the shoot occurs, and many leaves are suppressed. This fact may account for the final arrangement of the cushions being incomplete or difficult to trace in many trees.

Plate XLIV shows projections of trees in which it is not possible to trace the cushion arrangement successfully. There are however indications of a general spiral arrangement.

The fact that cacao cushions are borne according to the system of phyllotaxis of the tree is of interest. The appearance of spirals which are suppressed in the juvenile stage is of still further interest, for it provides material for investigation in both the ontogeny and phylogeny of cacao. We are accustomed to look for evidence of ancestral characteristics in juvenile forms. Are these spirals, which are suppressed in the juvenile stage, and developed in the adult, a characteristic of the recent evolution of cacao, or are they indicative of an ancestral form in which the leaves were linear and closely packed, the habitat of which was possibly of a more xerophytic nature ?

Other cauliferous trees are worth examination in the light of the facts now published.

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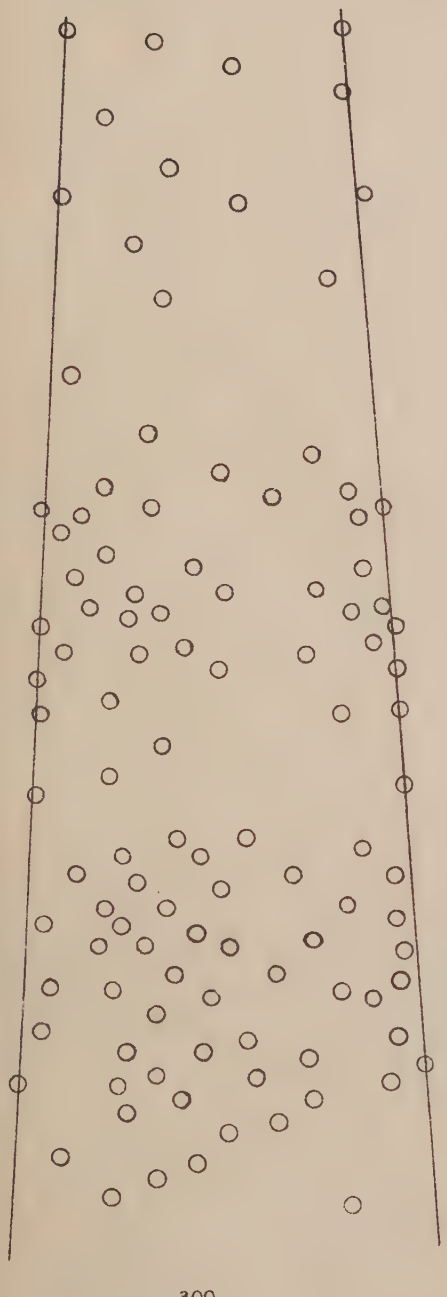
While this article was in the press the writer had access, in literature not hitherto available, to an important and extremely interesting contribution on the subject i.e., an article entitled " Ueber die Inflorescenzen von *Theobroma cacao* Linn. und *Theobroma bicolor* Humb. und Ihre Umformung unter den Einfluss des Krullotenschimmels (*Marasmius perniciosus* Stahel)." by Gerold Stahel, in Annales du Jardin Botanique de Buitenzorg, 20 Serie, Bol. XV, pp. 95–114, 1918..

Stahel studied the inflorescences of *T. cacao* and *T. bicolor* in work on Witch Broom disease, and describes their morphology and development in detail.

He also observes that the *inflorescences have their origin in the axils of the original leaves of the axis*, a fact also recorded in the present article before the writer was aware of Stahel's previous work.



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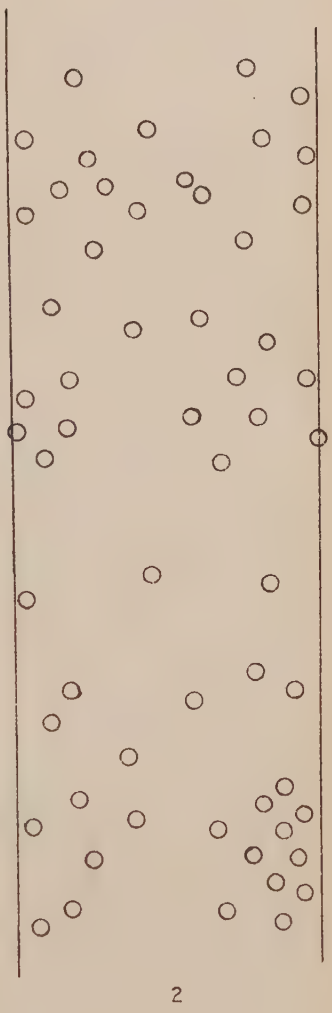

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PLATE XLIV. PROJECTION OF TRUNKS ON WHICH THE ARRANGEMENT OF CUSHIONS CANNOT BE CLEARLY TRACED.

## PAPER No. XX.

# SURVEY OF RICE AREAS IN THE WESTERN PROVINCE.

By F. A. ROBB.

From the Annual Reports of the Customs Department the imports of rice and the value of imports during the past seven years are shown in the following table.

TABLE I.

| *Year.* | *Rice.* | *Value.* |
|---|---|---|
| — | *Tons.* | £ |
| 1921 .. .. .. | 3,220 | 93,471 |
| 1922 .. .. .. | 4,658 | 109,068 |
| 1923 .. .. .. | 7,205 | 141,832 |
| 1924 .. .. .. | 8,330 | 161,571 |
| 1925 .. .. .. | 9,200 | 180,189 |
| 1926 .. .. .. | 9,544 | 184,368 |
| 1927 .. .. .. | 10,303 | 201,925 |

It will be seen from the above table that the imports are annually becoming greater and it may be of interest to offer an explanation of this. Rice is used as a substitute for the ordinary starchy foods—plantains, yams, cassava and corn. The market for rice tends to be localised to the larger towns, mining centres, etc., where the population is dense and the supply of the ordinary foodstuffs somewhat erratic, especially during the rainy season. With the continual growth of towns and industrial centres it is to be expected that the imports of rice will show a corresponding increase.

The average number of acres cultivated per farmer appears to be about five. Reckoning imports at 10,000 tons and the yield per acre at 800 lbs., the total area of land necessary to produce this quantity of rice would be 10,000 x 2240/800 or 28,000 acres, and the number of farmers 28,000/5 or 5,600.

Results of experiments at Adebrem station in 1924–25 with 14 different varieties of rice gave yields varying from 64 lbs. per acre to 2,080 lbs. paddy. C. Saunders in his report on "Swamp Rice Cultivation in Sierra Leone" gives the average yield per acre as 1,434 lbs. paddy. 1,200 lbs. paddy, equivalent to 800 lbs. rice, is a reasonable estimate of the yield per acre in the area under survey.

## AREAS SURVEYED.

The rice area is fairly well defined, the Ancobra river forming the eastern limit and the Tano river and Juen lagoon the western limit.

The survey of this area has been divided into three areas corresponding to the three more or less distinct rice areas.

Area I embraces the area considered to lie within an economic distance of the Rice Mill at Esiama.

Area II. The Amonsuri area.

Area III. Half-Assini, Tano river and Juen lagoon areas.

In the map attached these areas are shown, the position of the various villages are marked and the main rivers and streams shown.

## ESIAMA AREA.

The following Table II shows the number of farmers in each village of the Esiama area likely to embark on the industry.

TABLE II.

**List of villages and number of farmers.**

| *Name of village.* | *No. of farmers.* | *Name of village.* | *No. of farmers.* |
|---|---|---|---|
| Atiakrom | 5 | Asanta | 80 |
| Apatem | 10 | Pompreman | 3 |
| Nanwa | 5 | Asemko | 8 |
| Asuoti | 10 | Kickam | 40 |
| Esuomi | 30 | Asrunun | 28 |
| Ahiem | 30 | Esiama | 85 |
| Atrakaso | 20 | Mpien | 29 |
| Kokofri | 40 | Nyensi | 15 |
| Aniben | 42 | Bakanta | 20 |
| Dominasi | 3 | Sensuri | 43 |
| Bamyankaw | 33 | Krisan | 37 |
| Akakrom | 11 | Asangrun | 18 |
| Ablabo | 7 | Nyensi | 5 |
| Adasu | 4 | Anuku | 3 |
| Asinwia | 8 | Nkoraba | 4 |
| Akanko | 35 | Bentinaboa | 5 |
| Afranse | 34 | Kamponae | 4 |
| Kohuri | 7 | Aro Bokaso | 5 |
| Mpansi | 28 | Amishibiebokaso | 20 |
| Akasuno | 6 | Apentua | 16 |
| Aurobo | 3 | Jiakpole | 15 |
| Nyemasi | 8 | Awiabo | 55 |
| Bausu | 80 | Basaka | 41 |
| Ekpule | 3 | Aiyinasi | 90 |
| Asundi | 3 | Akoto | 10 |
| Atakrom | 17 | Alopoke | 7 |
| Onsiama | 4 | Tantan | 5 |
| Adebrem | 23 | Achirichi | 5 |
| Bou | 18 | Ekpoko | 3 |
| Ninzimrim | 15 | Ebi | 6 |
| Bomopole | 60 | Kenyamesu | 3 |
| Nkrofo | 28 | Adubra | 8 |
| Teko Bokaso | 5 | Akasuno | 4 |
| Ngugro | 3 | Beswasaso | 3 |
| Akurago | 2 | Auraso | 5 |
| Berekrom | 4 | | |
| | 644 | | 728 |

# RICE AREAS

## EASTERN AND WESTERN NZIMA

Plate No XLVII.

Survey H.Q. Accra, 1929.

Production possible in Area I,

$$= \frac{1372 \times 800 \times 5}{2240} \text{ or } 2450 \text{ tons rice}$$

Equivalent to $\frac{2450 \times 100}{65}$ or 3,770 tons paddy.

According to the maker's estimate the mill should be capable of an output of 10 cwts. of cleaned rice per hour. Results so far obtained, however, seem to indicate that 6 cwts. per hour is nearer the figure. Later on, when paddy becomes more uniform in sample, the output may increase.

Accepting 6 cwts., as the average output of cleaned rice per hour, the capacity of the mill may be rated at 700 tons per annum, equivalent to 1,000 tons of paddy. It has been shown above that the estimated production of Area I is 3,770 tons of paddy.

## AMONSURI AREA.

The following Table shows the number of farmers, in each village of the Amonsuri area, likely to embark on the industry :—

### Table III.

### List of villages and number of farmers.

| *Name of village.* | *No. of farmers.* | *Name of Village.* | *No. of farmers.* |
|---|---|---|---|
| Eikwe .. .. .. .. | 40 | Nzurazo .. .. .. | 3 |
| Ngalikpole .. .. .. | 35 | Nyejina .. .. .. | 7 |
| Ngalichi .. .. .. | 30 | Boluan .. .. .. | 30 |
| Beku .. .. .. .. | 21 | Mpen .. .. .. .. | 8 |
| Anochi .. .. .. .. | 20 | Bewia .. .. .. .. | 10 |
| Atwabo .. .. .. .. | 50 | Nyelenu .. .. .. | 9 |
| Kaboku .. .. .. | 15 | Tukobo .. .. .. | 40 |
| Beyin .. .. .. .. | 100 | Samengyi .. .. .. | 50 |
| Merekazo .. .. .. | 10 | Ezuriti .. .. .. | 7 |
| Aloen .. .. .. .. | 65 | Mpataba .. .. .. | 60 |
| Kangan .. .. .. .. | 56 | Nuba .. .. .. .. | 47 |
| Twenani .. .. .. .. | 45 | Tikwabo .. .. .. | 55 |
| Ajesa .. .. .. .. | 50 | Alawuri .. .. .. | 80 |
| Alanganzure .. .. .. | 60 | Awalka .. .. .. | 40 |
| Zinabo .. .. .. .. | 50 | Ahonozo .. .. .. | 60 |
| Bonyere .. .. .. | 150 | Alumkazo .. .. .. | 20 |
| Ndumwaso .. .. .. | 10 | Puntsin .. .. .. | 10 |
| Nauli .. .. .. .. | 15 | Menseso .. .. .. | 25 |
| | 822 | | 561 |

Total number of farmers = 1,383.

Production possible in Area II = $\frac{1383 \times 800 \times 5}{2240}$ or 2,470 tons rice.

Equivalent to $\frac{2470 \times 100}{65}$ or 3,800 tons paddy.

A suitable site for a mill in this area would probably be in the neighbourhood of Beyin. It is the seat of the Omanhene of Western Nzima and most of the villages listed in Table III come under his jurisdiction. The sufferance port of Atwabo lies about two miles distant and there would be no difficulty in marketing the rice.

## JUEN AREA.

The following Table shows the number of farmers, in each village of the Juen area, likely to embark on the industry :—

TABLE IV.

**List of villages and number of Farmers.**

| *Name of village.* | *No. of farmers.* | *Name of village.* | *No. of farmers.* |
|---|---|---|---|
| Bokakre .. .. .. | 5 | Avlium .. .. .. | 10 |
| Kobnaswaso .. .. .. | 50 | Dublimbo .. .. .. | 5 |
| Ebwazo .. .. .. .. | 60 | Nokaben .. .. .. | 20 |
| Tobo .. .. .. .. | 40 | Jewi Ahonozo .. .. | 4 |
| Atwinbanso .. .. .. | 15 | Fetekoro .. .. .. | 10 |
| Epung .. .. .. .. | 25 | Saporazo .. .. .. | 3 |
| Half-Assini .. .. .. | 130 | Edu .. .. .. .. | 60 |
| Metika .. .. .. .. | 30 | Epunwanta .. .. .. | 7 |
| Jewi .. .. .. .. | 50 | Techinta .. .. .. | 45 |
| Anomatuepin .. .. .. | 25 | Alenda .. .. .. | 50 |
| Nzimitienu .. .. .. | 26 | Tano River area (say) | 400 |
| Manjia .. .. .. .. | 30 | | |
| Efusa .. .. .. .. | 20 | | 614 |
| Newtown .. .. .. | 34 | | |
| | 540 | | |

Total number of farmers = 1,154.

Production possible in Area III = $\frac{1154 \times 800 \times 5}{2240}$ or 2,050 tons rice

Equivalent to $\frac{2050 \times 100}{65}$ or 3,150 tons paddy.

There is a very suitable site for a mill in this area near the Juen lagoon as shown marked on the map. It would be sufficiently far inland not to be affected by the sea and conveniently situated for farmers bringing paddy by canoes. There is easy communication to Half-Assini along a light railway. The rice would be shipped from there to Sekondi and other markets.

A study of the map will show that there is ample land available in the three areas surveyed to produce far more than 10,000 tons of rice. The limiting factor in production is population or a sufficient number of farmers to work the land. It is to be expected that many of the people, who left the different villages in search of work in other centres, will gradually return, a tendency already noted at Esiama.

## RAINFALL.

The monthly distribution of rainfall during the past five years is given in Table V. The figures are for Axim but are typical of all parts of the rice area :

TABLE V.

| Month. | 1923 | | 1924 | | 1925 | | 1926 | | 1927 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Days. | Inches. | Days. | Inches. | Days. | Inches. | Days. | Inches. | Days. |
| January | 0.97 | 1 | 1.17 | 3 | 0.45 | 1 | 0.99 | 4 | 0.80 | 1 |
| February | 0.98 | 3 | 1.46 | 2 | 0.55 | 4 | 2.38 | 4 | 4.32 | 5 |
| March .. | 11.29 | 10 | 2.01 | 7 | 12.25 | 16 | 3.26 | 8 | 6.73 | 9 |
| April .. | 1.64 | 7 | 5.15 | 16 | 6.06 | 10 | 0.81 | 5 | 1.77 | 4 |
| May .. | 30.26 | 26 | 8.41 | 13 | 5.75 | 18 | 17.97 | 22 | 12.48 | 21 |
| June .. | 19.34 | 16 | 11.68 | 15 | 26.26 | 25 | 26.58 | 27 | 22.61 | 26 |
| July .. | 7.59 | 12 | 7.35 | 6 | 11.63 | 12 | 7.26 | 29 | 1.87 | 24 |
| August .. | 0.46 | 1 | 1.03 | 5 | 1.37 | 8 | 0.79 | 21 | 0.42 | 14 |
| September | 2.64 | 7 | 2.07 | 12 | 2.36 | 8 | 5.94 | 22 | 0.73 | 11 |
| October.. | 6.86 | 9 | 8.40 | 14 | 0.12 | 3 | 8.6 | 25 | 7.37 | 21 |
| November | 6.89 | 10 | 6.13 | 13 | 0.69 | 5 | 8.90 | 19 | 8.04 | 17 |
| December | 1.26 | 3 | 6.96 | 9 | 1.92 | 5 | 1.48 | 3 | 6.87 | 13 |
| Total .. | 90.18 | 105 | 61.82 | 115 | 69.41 | 115 | 84.96 | 189 | 74.01 | 166 |

It will be seen from the above table that the distribution of rainfall during the two wet periods varies little from year to year. Furthermore the heaviest deposition of rain in the Colony corresponds closely to the area under survey as shown in the rainfall contour map published in the 1927 Year Book.

A high rainfall, evenly distributed, is an important factor in the successful cultivation of rice, which requires ample moisture during a definite period of its growth. It is possible for farmers to harvest two crops in the year and although few at present do so the practice will probably become more general later on.

## TRANSPORT.

It has been shown in the preceding paragraphs that two additional mills are considered necessary for the development of the rice industry. The farmers in the areas surveyed are without an economic agricultural industry, and with imports valued at £200,000 the erection of these mills appears justified.

The easy transportation of paddy to the various mills is important. Reference to the Map will show the different routes paddy would be brought to the various centres. Waterways are indicated in blue, lorry roads in red, and paths by dotted lines. The beach can only be used during low tide.

In all three areas waterways cover the greater part of the area and paddy may be brought considerable distances at comparatively small cost.

Apart from the beach the only motorable roads are to be found in the proximity of Esiama. The road connecting Esiama to the Amonsuri Lagoon is under construction and it is hoped to have it completed before the opening of the mill on September 17th.

During last milling season farmers continually complained of the high rate charged by lorry owners conveying paddy to the mill. There are few cars in the district and, with lack of competition, rates are consequently high, as shown in the following table :—

| *Village.* | *Miles to Factory.* | **Rates charged.* | *Equivalent to per ton mile.* |
|---|---|---|---|
| Ancobra .. .. | 7 | 11/– | 4/2½d. |
| Asanta .. .. | 5½ | 10/– | 4/10¼d. |
| Kickam .. .. | 2 | 5/– | 6/8d. |
| Esiama .. .. | 1½ | 3/– | 5/4d. |

*These rates are for 6 bags of 140 lbs. each.

## MARKETING.

Having shown that there is land available, and a sufficient number of farmers to interest themselves in the rice industry and that conditions are favourable for the development projected, it now becomes necessary to consider the question of the disposal of the produce.

There is a definite and certain market for rice within the country. The problem is to find the best way of getting it there with most profit to the farmers. This is important as the success of the industry will to a very large extent depend upon the price the farmers are going to obtain for their produce. It is unlikely that they will interest themselves long in an industry that demands hard and patient work if it is not going to prove sufficiently remunerative.

To arrive at a satisfactory solution of the problem there are certain factors to be considered :—

(*a*) Villages in the vicinity of which rice is grown tend to be self-contained.

(*b*) Farmers are almost entirely illiterate.

(*c*) A certain amount of inherent jealousy exists between most villages.

(*d*) Road Transport. The maximum load permitted on the Ancobra-Esiama road is 10 cwts. and Ancobra-Sekondi 1 ton. In addition there is a toll of 5/- at the Ancobra Ferry on lorries plus a charge of 1d. per 25 lb. bag of rice.

(*e*) Farmers wish to dispose of their rice for immediate cash.

A consideration of the above points makes it evident that it would be inadvisable at the present time to attempt a system of co-operative marketing. It is also clear that road transport is prohibitive in cost and that rice must be conveyed to the markets by the cheaper sea route.

The distribution of the rice in several markets is outside the farmers' duties. It is here that the merchant steps in and with his organisation is able to distribute the rice over a wide area. It is clear that a simple and effective method of marketing, without the intervention of a middleman, is possible by the farmers selling direct to a trading firm.

This method was adopted last year and met with the general approval of the farmers.

## PAPER No. XXI.

# THE RICE INDUSTRY—EASTERN NZIMA.

By F. A. ROBB.

It is frequently stated that rice was introduced to the Gold Coast within comparatively recent times, but a study of the Nzima people and their traditions indicates a much older origin. It is significant that one of the divisions is called "Azanvre" (Azan—rice, vre—people) a name which is historically old.

According to the tradition of the Nzima tribes their original home was the Nile, and at the period of Mohammedan aggression in the 14th and 15th centuries they migrated westwards, eventually settling along the Guinea Coast.* If this belief is accurate then there is every reason to suppose that rice, being one of their staple food crops, was introduced into the country by these early settlers.

## A. THE INDUSTRY.

### The Rice Area.

The Nzima rice area extends from the Ancobra river to the Tano river and its lagoons, as outlined in the map. (*See* Plate XLVIII). Throughout this area rice can be grown, but at the present time only the eastern section around Esiama is being developed.

### Suitability of the Area for Rice.

The successful cultivation of rice depends upon an adequate supply of moisture and a fairly high air temperature, conditions which undoubtedly exist in this part of the country. Reference to the rainfall map of the Gold Coast (Plate XXIII Year-Book 1927) shows that the area outlined above lies within the zone of the heaviest deposition of moisture.

There are two definite periods of rainfall—the major rains occurring in April–July and the minor rains in October–December. (Table I). Corresponding to these rains two crops of rice can be grown annually, a major and a minor crop.

The country is low lying in character and well watered, much of it is, in fact, swampy and marshy, while the areas slightly above normal water level have good alluvial soils very suitable for the cultivation of rice.

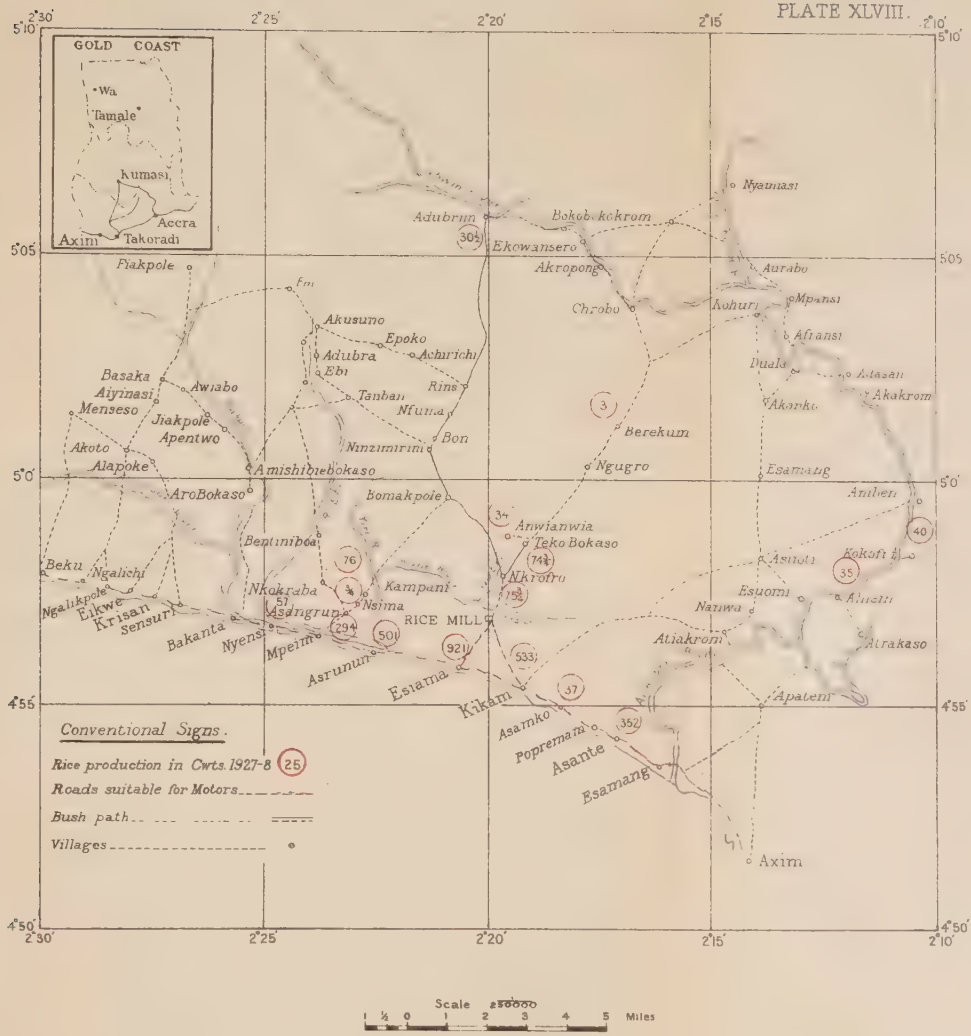
The people, too, in the Nzima country, have hitherto had no economic agricultural crop which they could send to other parts of the Colony or export, and they are eager to take advantage of the development of the industry.

These factors, a fairly high air temperature, good soil, heavy rainfall and suitable land not occupied by other crops together with a willingness of the people to increase greatly the area planted with rice, may be taken as indicating great possibilities in the future development of the industry.

*(Vide Gold Coast Review, Vol. I. No. 1. "The History of Nzima up to 1847 by R. W. Sanderson.")

# ESIAMA RICE MILL AREA.

PLATE XLVIII.




Survey H. Q. Accra, 1929.

TABLE I.

| | Month. | 1921 | | 1922 | | 1923 | | 1924 | | 1925 | | 1926 | | 1927 | | 1928 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Rainfall inches. | No. of days rain fell. | Rainfall inches. | No. of days rain fell. | Rainfall inches. | No. of days rain fell | Rainfall inches. | No. of days rain fell. | Rainfall inches. | No. of days rain fell. | Rainfall inches. | No. of days rain fell. | Rainfall inches. | No. of days rain fell. | Rainfall inches. | No. of days rain fell. |
| | January .. | — | — | 1.55 | 1 | 0.97 | 1 | 1.17 | 3 | 0.45 | 2 | 1.19 | 4 | 0.80 | 1 | 1.65 | 3 |
| | February .. | — | — | — | — | 0.98 | 3 | 1.46 | 2 | 0.55 | 4 | 2.38 | 4 | 4.32 | 5 | 0.95 | 1 |
| | March .. | — | — | 6.66 | 12 | 11.29 | 10 | 2.01 | 7 | 12.25 | 16 | 3.26 | 8 | 6.73 | 9 | 4.09 | 6 |
| Major Rains | April .. | — | — | 2.71 | 8 | 1.64 | 7 | 5.15 | 16 | 6.06 | 10 | 0.81 | 5 | 1.77 | 4 | 4.44 | 9 |
| Major Rains | May .. | — | — | 6.12 | 17 | 30.26 | 26 | 8.41 | 13 | 5.75 | 18 | 17.97 | 22 | 12.48 | 21 | 23.57 | 16 |
| Major Rains | June .. | — | — | 19.63 | 17 | 19.34 | 16 | 11.68 | 15 | 26.26 | 25 | 26.58 | 27 | 22.61 | 26 | 26.22 | 12 |
| Major Rains | July .. .. | 13.01 | 19 | 0.38 | 3 | 7.59 | 12 | 7.35 | 6 | 11.63 | 12 | 7.27 | 29 | 1.87 | 24 | — | — |
| | August .. | 5.14 | 8 | 0.34 | 3 | 0.46 | 1 | 1.03 | 5 | 1.37 | 8 | 0.79 | 21 | 0.42 | 14 | — | — |
| | September .. | 10.29 | 14 | 2.52 | 10 | 2.64 | 7 | 2.10 | 12 | 2.36 | 8 | 5.94 | 22 | 0.73 | 11 | — | — |
| Minor Rains | October .. | 2.84 | 6 | 10.43 | 17 | 6.86 | 9 | 8.40 | 14 | 0.12 | 3 | 8.60 | 25 | 7.37 | 21 | — | — |
| Minor Rains | November .. | 18.21 | 12 | 5.64 | 17 | 6.89 | 10 | 6.13 | 13 | 0.69 | 5 | 8.90 | 19 | 18.04 | 17 | — | — |
| Minor Rains | December .. | 5.49 | 6 | 4.39 | 8 | 1.26 | 3 | 6.96 | 9 | 1.92 | 5 | 1.48 | 3 | 6.87 | 13 | — | — |
| | Total .. .. | — | — | — | — | 90.18 | 105 | 61.85 | 115 | 69.41 | 116 | 85.17 | 189 | 84.01 | 166 | — | — |

**Varieties of Rice.**

A primary classification consists in differentiating lowland or swamp varieties from upland or hill rice.

The varieties grown locally appear to fall naturally into the first group. There are several distinct types, both red and white, distinguished by the presence or absence of an awn and the relative sizes of the grains.

The variety which has been found most satisfactory, from both the milling and the marketing points of view, is a medium sized grain, white and without awn. Red rice, although preferred in this district to white rice, is not readily marketable in the other consuming centres and its cultivation is being gradually stopped. Similarly, the cultivation of varieties which have long cylindrical grains is not recommended as the grains tend to break in the milling process and an unduly high percentage of broken rice results in the finished product.

**Method of Cultivation.**

Rice, in common with most other annual crops grown in the Colony, is cultivated on the moving farm system. A piece of land is cleared, the bush and vegetation burnt, the land tilled to some small extent and the seed sown broadcast on it at the commencement of the rains, usually as early in April as the occurrence of rain permits. After sowing the ground is lightly hoed to ensure retention of the seed in the soil and as a protective measure against birds. Each field is then enclosed by a fence three to four feet high to safeguard the young rice plants from certain animals, notably the " cutting-grass " a type of guinea pig, which has been known to cause severe damage and financial loss to the farmer.

Towards the end of April the rivers and streams, swollen by the rains, flood the rice fields. No further attention is given, the outcome being left to nature until the grain is ready for ripening, which commences in early August. This is an anxious time for the farmer, who has to be continually on the alert in protecting his crop from the numerous flocks of birds which appear. Temporary dwellings, which are, later, used as store houses for the paddy, are erected in or near the paddy fields, and considerable ingenuity is displayed in the different methods of frightening the birds.

Harvesting, which commences towards the end of August, is laborious and tedious. Each head of grain is cut separately, and, in small bundles, laid on the ground to dry, before being removed to the temporary houses and stored. When sufficiently dried the paddy is spread out on a floor and the grain separated from the straw by treading. The straw is raked aside and the threshed grain separated from the chaff by natural winnowing.

*Photo by J. A. C. Holm.*

RICE FACTORY, ESSIAMA.

PLATE L.

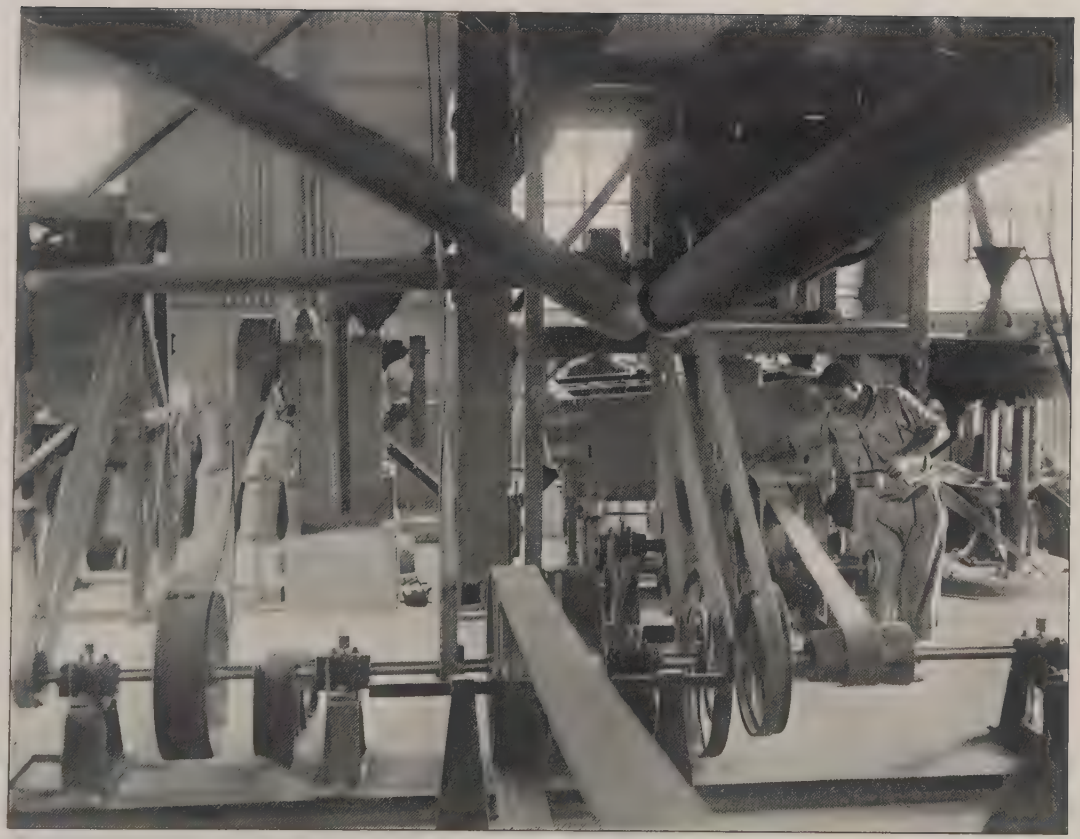


*Photo by J. A. C. Holm.*

RICE FACTORY, ESSIAMA—INTERIOR.

The land from which the crop was harvested is allowed to revert to bush, and the following season another piece of land is selected on which to make the rice farm, the original land not being used again for three to four years.

**The Rice industry in relation to food production within the Colony.**

The amount of rice imported into the Colony, has been steadily increasing since 1922, as shown in Table II.

TABLE II.

| *Year.* | *Tons-rice.* | *Value.* |
|---|---|---|
| | | £ |
| 1922 .. .. .. | 4,658 .. .. | 109,068 |
| 1923 .. .. .. | 7,205 .. .. | 141,832 |
| 1924 .. .. .. | 8,330 .. .. | 161,571 |
| 1925 .. .. .. | 9,200 .. .. | 180,189 |
| 1926 .. .. .. | 9,544 .. .. | 184,368 |
| 1927 .. .. .. | 10,303 .. .. | 201,925 |

There can be no doubt as to the soundness of an agricultural policy aimed at making a country self-supporting so far as local foods are concerned, and it has been shown above that in the Nzima country there exists a sufficient area of suitable land, suitable climate and a sufficient number of people to engage in the industry to make it distinctly hopeful that, in the near future, a considerable portion of the rice consumed in the Gold Coast will be grown in the Colony.

Rice has the advantages of being a crop that can be stored, especially in the paddy form, for a considerable time without serious deterioration ; it can be readily transported from one end of the Colony to the other and is a form of starchy food agreeable to the people.

So far as quality is concerned the rice produced at the Government Mill is at least equal to that imported.

**Steps taken to foster industry.**

Practically no development of the industry would have been possible without a power driven mill, such as that erected by Government near Esiama. This, then, must be regarded as the first great step in the development of the industry. The next step was the provision of means whereby the grower could convert his paddy or rice into cash, readily and without trouble on his part. This problem has been solved. Another step in the fostering of the industry is the making of new, and the improvement of existing roads, so as to make the transport of the paddy to the mill easier.

## B. THE GOVERNMENT RICE-MILL.

### Site.

The initial development of the industry, as already mentioned, was confined to the district around Esiama, where rapid progress was almost certain to take place under the enlightened Ohene, Kofi Ampoe II.

A suitable site for the mill was selected one and a half miles inland from Esiama and situated more or less centrally in the rice area of that section of the country.

### Installation of Plant.

The rice machinery arrived in the Colony in July 1923, but was not installed until August of the following year. It was then found that the 25-h.p. Austin Tractor, which had been suggested should be used for the initial running was quite unsuited for this type of work. Further delay resulted and it was not until February of 1926 that the Plant was ready for testing. In the interval a 25-h.p. National gas engine had been installed.

### Description of Plant and Milling process.

The paddy as it is received at the factory is weighed. It is then passed through a hand winnower, where bits of straw, light grains and stones are removed, before being tipped into the paddy inlet hopper No. 1 ( Plate No. LI ). which feeds elevator No. 2.

This elevator conveys the paddy to the sheller No. 3, which removes the husk from the grain. The sheller has two cast iron discs covered with emery and carborundum composition. The upper disc is stationary and the lower disc, which rotates on its spindle, is adjustable, the distance between the faces of the discs being increased or decreased to suit the size and quality of the grain being treated. The adjustment of the discs is accomplished by means of a hand wheel working through a lever which raises or lowers the rotating shaft.

The material delivered from the sheller consists of shelled rice, broken rice, husk, a small quantity of meal ( small broken rice ) and a proportion of paddy which is passed through the machine unshelled. This assorted product is delivered to elevator No. 4, which delivers the material into a reciprocating shaker No. 5 (placed over the husk aspirator No. 5) which removes the meal and small broken rice ; the shelled rice, broken rice, husk and paddy delivered from the shaker is fed direct to the husk aspirator No. 5. This machine is a system of louvres over which the stock passes and by means of a powerful suction fan the husk is removed and blown to cyclone No. 12.

# REFERENCE TABLE.

## DESCRIPTION.

Scale $\frac{3}{8}'' = 1$ Foot.

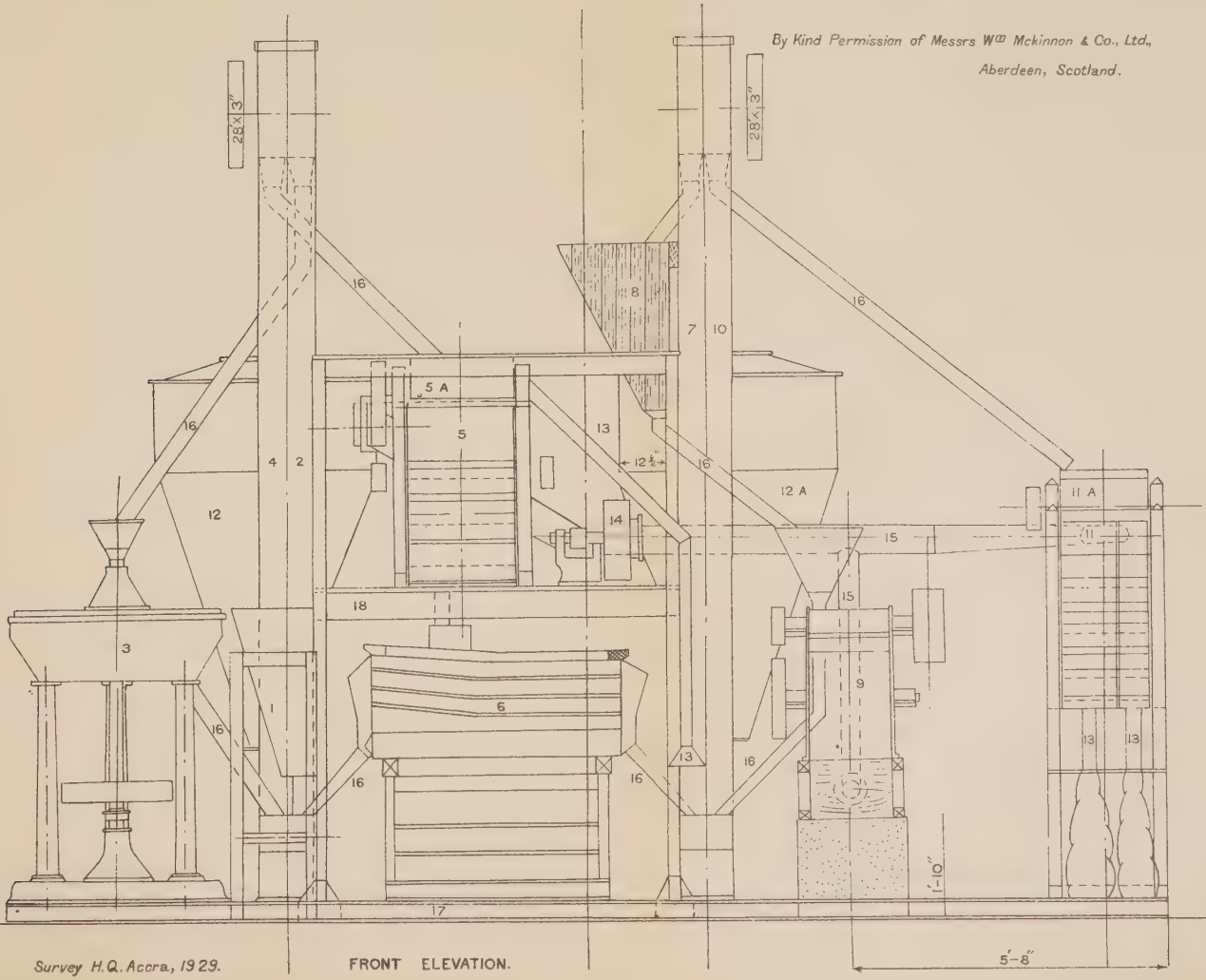
Nº

1. PADDY INLET HOPPER.
2. ELEVATOR FOR PADDY 13'-0" CRS. 4" BUCKETS.
3. SHELLER 40" DIAM. (SELF-CONTAINED)
4. ELEVATOR FOR RICE & HUSKS 13'-0" CRS. 3" BUCKETS.
5. HUSK ASPIRATOR. SEPARATING RICE & HUSKS.
6. PADDY ELIMINATOR 18 COMPTS.
7. ELEVATOR FOR SHELLED RICE 13'-0" CRS 3" BUCKETS.
8. BIN FOR CARGO RICE.
9. RICE HULLER AND POLISHER Nº 1 SIZE.

Nº

10. ELEVATOR FOR WHITE RICE 13'-0" CRS. 3" BUCKETS.
11. ASPIRATOR FOR RICE AND BROKEN RICE.
12. CYCLONE DUST COLLECTOR 4'-0" DIAM.
13. DELIVERY SPOUTS.
14. SUCTION FAN 10" DIAM.
15. EXHAUST PIPING.
16. SHUTES & INTERCONNECTING PIPING.
17. STEEL FRAMEWORK.
18. WOODEN PLATFORM.

*By Kind Permission of Messrs Wm Mckinnon & Co., Ltd., Aberdeen, Scotland.*




*Survey H.Q. Accra, 1929.*

FRONT ELEVATION.

The product from the husk aspirator now consists of shelled paddy (rice) and unshelled paddy, and the separation of these is one of the most important operations in the mill. To obtain this separation which is effected on the basis of the specific gravity of the stock being treated, the grain is delivered to the paddy separator No. 6. The body of the machine is adjustable and consists of floors built one on top of the other, each floor having an equal number of compartments or peculiarly shaped chambers into which the grain is evenly fed from the feed box. The machine is mounted on rockers and a reciprocating motion is imparted by an eccentric keyed to the driving shaft. The speed of the machine varies according to the type of grain being treated, and to obtain this variation in speed, cone pulleys are provided.

The unshelled grain delivered from the machine is returned to the paddy elevator No. 2 and is again fed to the sheller. The shelled paddy is delivered to elevator No. 7 which conveys it to a hopper No. 8 conveniently arranged over the huller and polisher No. 9. This machine removes the outer covering or testa, and a rotating drum covered with leather strips gives a polish to the rice. The product, rice and broken rice, is conveyed by elevator No. 10 to the shaker No. 11A (placed over the rice aspirator No. 11) which removes a quantity of the broken rice. The rice is now finally aspirated in the rice aspirator No. 11, and bagged off at the bagging spouts.

No. 14 shows the suction fan for aspirating the rice in the huller and polisher and aspirator, and No. 12A the cyclone where the meal and small broken rice are collected.

The estimated output of the mill, according to the maker's figure, is 10 cwts. of cleaned rice per hour. This figure has not as yet been attained (Table V.). There is little doubt, however, that when the quality of the paddy and the size of the grain become more uniform the output of the mill will show a considerable increase over the figures obtained in season 1927–28.

**Relationship between the producer and the Factory.**

In return for converting the paddy into a condition ready for market, Government retains a percentage of the farmer's crop and in Colonel Ogilvy's scheme, which was approved, 8% was mentioned as the Government's share for the work done in the factory.

Tests were conducted and the following figures were obtained :—

| | |
|---|---|
| % of completely milled rice .. .. .. | 63 |
| % of rough rice (shelled only) .. .. | 75 |

Based on these figures the following table was compiled :—

TABLE III.

| For Rice Hulled and Polished. | | For Rough Rice (shelled only.) | |
|---|---|---|---|
| Weight of paddy. | Rice issued. | Weight of paddy. | Rice issued. |
| lbs. | lbs. | lbs. | lbs. |
| 10 | 5 | 10 | 6 |
| 20 | 11 | 20 | 13 |
| 30 | 17 | 30 | 20 |
| 40 | 23 | 40 | 27 |
| 50 | 29 | 50 | 34 |
| 60 | 34 | 60 | 41 |
| 70 | 40 | 70 | 48 |
| 80 | 46 | 80 | 55 |
| 90 | 52 | 90 | 62 |
| 100 | 58 | 100 | 69 |

In the above scheme it is apparent that the onus of marketing falls on the farmers. Unfortunately they have no desire to accept this responsibility and a serious set-back to the industry might have resulted if definite arrangements had not been made with one of the large trading firms in the Colony to purchase the rice.

**Two years' working.**

In the first season, 1926–27, 35 tons of paddy were milled, and in the second season, 1927–28, 155.9 tons. There is little doubt that the increase is due to an actual extension of area consequent upon the erection of the mill.

Monthly records of the milling figures obtained in the two seasons are shown in Tables VI and VII. In season 1927–28, in addition to rice output, the weights of the various by-products were obtained and recorded.

**Utilisation of By-products.**

The by-products obtained in the process of milling are as follows :—

(*a*) Husks.

(*b*) Small broken rice, dust, etc., from husk aspirator Shaker.

(*c*) Meal and bran.

(*d*) Broken rice.

(*a*) The high calorific power of rice husks makes it of considerable value as a fuel. It can be burned in furnaces to produce steam or used in gas producers, and the writer is of opinion that the utilisation of the husks is well worth consideration and that the oil engine at the factory might with advantage be replaced by a gas producer engine.

(*b*) The material delivered from the husk aspirator shaker makes a useful poultry food.

(*c*) The meal and bran are foods of high nutritive value, and in many countries, are used as component parts in the manufacture of compound cattle feeding cakes. Unfortunately no demand exists on the coast for cattle foods, and it has not yet been possible to find an outlet for this exceedingly valuable by-product.

(*d*) The broken rice is disposed of locally and is used in the preparation of "rice kenky" or "pancakes." In the latter case the rice is pounded, mixed with ripe plantain and fried in palm-oil.

**Financial aspect of the rice Factory.**

The capital cost of the Rice Factory to the end of the financial year 1926, amounted to £3,256 os. 7d. Statements of revenue and expenditure for the financial years 1926–27 and 1927–28 have been prepared and are shown below. The following annual charges have been allowed :—

| | £ | s. | d. |
|---|---|---|---|
| Interest on capital, 6% on £3,256 os. 7d. .. .. | 195 | 7 | 3 |
| Depreciation on plant 10% on £2,180 4s. 3d. .. .. | 218 | 0 | 5 |
| Depreciation on house 5% on £446 2s. 10d. .. .. | 20 | 6 | 2 |
| Insurance on £3,256 os. 7d. at 2½% .. .. .. | 81 | 8 | 0 |
| Total .. .. | 515 | 11 | 10 |

FINANCIAL YEAR 1926–27 (1st April, 1926–31st March, 1927).

| *Revenue.* | £ | s. | d. | *Expenditure.* | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| Sales .. .. | 51 | 8 | 3 | Milling costs .. | 280 | 3 | 5 |
| Net loss .. | 758 | 4 | 8 | Spares .. .. | 13 | 17 | 8 |
| | | | | Int. on capital, etc... | 515 | 11 | 10 |
| | £809 | 12 | 11 | | £809 | 12 | 11 |

FINANCIAL YEAR 1927–28 (1st April, 1926–31st March, 1928).

| *Revenue.* | £ | s. | d. | *Expenditure.* | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| Sales .. .. | 157 | 6 | 7 | Milling costs .. | 304 | 19 | 0 |
| Net loss .. | 786 | 7 | 8 | Spares .. .. | 124 | 3 | 5 |
| | | | | Int. on capital, etc... | 515 | 11 | 10 |
| | £944 | 14 | 3 | | £944 | 14 | 3 |

If we omit for the moment Interest on capital, depreciation and insurance the loss in milling for the year 1926–27 was £242 12s. 10d. and for the year 1927–28 £271 15s. 10d. At the end of the latter year there remained rice on hand valued at £130 so that the actual loss for the year 1927–28 was only £140 15s. 10d.

**Analysis of milling costs.**

An analysis of the milling costs for the financial years 1926–27 and 1927–28 have been made and are shown in the following two tables :—

FINANCIAL YEAR 1926–27.

Milling costs £280 3s. 5d. Total paddy milled 35.17 tons.

| *Head of Expenditure.* | *Amount.* | *Expenditure per ton of paddy milled.* |
|---|---|---|
| | £ s. d. | £ |
| Labour .. .. .. .. | 225 12 10 | 6.42 |
| Kerosene .. .. .. .. | 22 6 3 | .63 |
| Freight and Transport .. .. | 13 8 7 | .38 |
| Miscellaneous charges, repairs, etc. | 18 5 9 | .53 |
| Total .. .. | £280 3 5 | £7.96 |

TABLE V.

FINANCIAL YEAR 1927–28.

Milling costs £304 19s. Total paddy milled 128.42 tons.

| *Head of Expenditure* | *Amount.* | *Expenditure per ton of paddy milled.* |
|---|---|---|
| | £ s. d. | £ |
| Labour .. .. .. .. | 226 14 1 | 1.76 |
| Kerosene .. .. .. .. | 52 6 10 | .41 |
| Grease and Waste .. .. .. | 1 6 11 | .01 |
| Freight and Transport .. .. | 8 10 6 | .07 |
| Miscellaneous charges, repairs, etc. | 16 8 1 | .13 |
| Total .. .. | £305 16 5 | £2.38 |

It will be noted that in the two years the milling costs per ton of paddy show an appreciable difference. The capacity of the mill is estimated at 1,200 tons of paddy per annum and when dealing with this quantity the cost of milling will probably be reduced to 15/– per ton.

# TABLE VI.

## SEASON 1926–27.

| Month. | Paddy. | Winnowing. | | | Milling. | | Percentage Rice to Clean Paddy. |
|---|---|---|---|---|---|---|---|
| | | Clean Paddy | Loss in Weight | % loss. | Polished Rice | Broken Rice | |
| | lbs. | lbs. | lbs. | | lbs. | lbs. | |
| October .. .. .. .. .. .. .. .. | 850 | 850 | — | — | 539 | — | 63.6 |
| December .. .. .. .. .. .. .. .. | 6,815 | 6,815 | — | — | 4,318 | 199 | 66.2 |
| January .. .. .. .. .. .. .. .. | 10,899 | 10,899 | — | — | 7,085 | 458 | 69.2 |
| January .. .. .. .. .. .. .. .. | 22,881 | *22,471 | 410 | 1.8 | 15,351 | 766 | 71.7 |
| February .. .. .. .. .. .. .. .. | 37,832 | 37,289 | 543 | 1.4 | 24,471 | 1,289 | 69.7 |
| Total .. .. .. .. .. | 79,277 | 78,324 | — | — | 51,764 | 2,712 | 69.6 |

*Winnowing of Paddy commenced latter half of January.

## TABLE VII.

SEASON 1927–28.

| Month. | Paddy. | Winnowing. | | Milling. | | | | | Percentage rice to paddy. | No. of hours milling. | | Output per hour. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Clean paddy. | % loss. | Polished rice. | Broken rice. | Dust, etc., from husk asp. shaker. | Meal and bran from huller and polisher. | Husk (obt. by balance). | | | | |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | | H. | M. | lbs. |
| September .. | 2,773 | 2,749 | 0.9 | 1,755 | 105 | 195 | 204 | 490 | 67.7 | 6 | — | 310 |
| October .. .. | 7,122 | 7,020 | 1.5 | 4,740 | 234 | 380 | 453 | 1,208 | 70.9 | 8 | 5 | 616 |
| November .. | 25,865 | 25,507 | 1.4 | 16,994 | 773 | 644 | 2,362 | 4,613 | 69.7 | 30 | — | 592 |
| December .. | 43.749 | 43,067 | 1.6 | 29,336 | 1,476 | 1,198 | 3,678 | 7,370 | 71.5 | 63 | 40 | 484 |
| January .. | 75,209 | 73,668 | 2.0 | 49,676 | 2,005 | 2,094 | 6,645 | 13,228 | 70.2 | 100 | 45 | 513 |
| February .. | 85,516 | 84,350 | 1.4 | 56,799 | 2,877 | 2,056 | 7,844 | 14,744 | 70.7 | 120 | 5 | 497 |
| March .. .. | 47,430 | 46,317 | 2.3 | 30,438 | 1,616 | 1,162 | 4,183 | 8,908 | 69.2 | 80 | 35 | 398 |
| April .. .. | 27,956 | 27,268 | 2.4 | 18,450 | 998 | 571 | 2,217 | 5,032 | 71.4 | 50 | 5 | 386 |
| May .. .. | 33,657 | 33,220 | 1.3 | 22,292 | 1,375 | 908 | 2,451 | 6,194 | 71.2 | 30 | 15 | 782 |
| Total .. .. | 349,277 | 342,966 | 1.87 | 230,480 | 11,459 | 9,208 | 30,037 | 61,787 | 70.5 | 489 | 50 | 494.7 |
| % Paddy | | | | 67.2% | 3.3% | 2.7% | 8.7% | 18% | | | | |

Although the financial statements in the preceding paragraph do not appear very encouraging the financial success of the Rice Factory is assured with increase of production. It has to be remembered too that a new industry is being developed and a loss must be expected in the first few years until the industry is thoroughly established. The increase of production which has taken place in the two years is distinctly encouraging and augurs well for the future.

**The future of the rice industry.**

The past two years' operation of the Mill has shown that the rice industry is capable of considerable development. During the year an agricultural survey of the Nzima country was completed and from the information gathered it has been suggested that two other mills should be erected, one near Half-Assinie and the other in central Nzima, between Atwabo and Beyin.

It is to be hoped that their erection will not be long delayed and that in the near future the Colony will be able to grow sufficient rice to meet its own requirements.

PAPER No. XXII.

# YIELDS OF COFFEE ON EXPERIMENT STATIONS, SUMMARISED TO THE END OF 1927.

By H. B. Waters.

During the years 1909 to 1913 small trial plots of coffee were established at each of the main experiment stations of the Department of Agriculture. The yield records, which were published each year in the Annual Reports of the Department, are summarised in this paper.

## EXPERIMENT STATIONS.

Brief particulars of the seven stations at which these plots were established are given below.

| | Distance from sea. Miles. | Elevation. Feet. | Rainfall records*. Min. inches. | Max. inches. | Average inches. |
|---|---|---|---|---|---|
| Aburi .. .. .. | 20 | 1,450 | 32 | 73 | 47·79 |
| Kumasi .. .. | 112 | 850 | 40 | 70 | 58.50 |
| Wiawso .. .. | 86 | 850 | 40 | 73 | 56.99 |
| Peki-Blengo .. .. | 53 | 750 | 36 | 68 | 52.09 |
| Tarkwa.. .. .. | 32 | 300 | 48 | 95 | 68.42 |
| Asuansi .. .. | 14 | 330 | 39 | 74 | 50.07 |
| Kibi .. .. .. | 48 | 940 | 46 | 80 | 64.96 |

## COFFEE VARIETIES.

Four varieties of coffee were grown, viz., Liberica, Robusta, Stenophylla and Arabica. Liberica is native to West Africa; it is a hardy and strong-growing variety which thrives at low altitudes and yields coffee beans of comparatively low quality. Robusta was discovered growing wild in the Congo by Emil Laurent in 1898. It is now by far the most popular variety in Java, where it thrives best at elevations of from 1,000 to 3,000 feet. As its name implies, this variety is exceedingly robust, and in addition it comes into bearing early and produces beans of good quality and flavour. Stenophylla was obtained from Sierra Leone, where it flourishes in the highlands; slow to come into bearing, it yields small beans of high quality. Arabica is the main variety of the world; it thrives best at altitudes between 2,000 and 4,000 feet and its beans produce a coffee of excellent flavour.

*Rainfall Map, Year Book, Department of Agriculture, Gold Coast 1927.

## MEAN YIELDS OF COFFEE PLOTS.

The yield records are given in Tables I, II, III, and IV at the end of this paper, from which the Mean Yields given in the following summary have been extracted :—

Pounds of Clean Beans (Husked) Per Acre.

| Variety | Aburi. | Kumasi. | Wiawso. | Peki-Blengo. | Tarkwa. | Asuansi. | Kibi. | Mean. |
|---|---|---|---|---|---|---|---|---|
| Liberica .. | 398 | 375 | 372 | 321 | 244 | 188 | 78 | 282 |
| Robusta .. | 222 | 265 | 189 | 390 | 356 | 157 | 206 | 255 |
| Stenophylla | 226 | 162 | — | 94 | 167 | 91 | — | 148 |
| Arabica .. | — | 36 | — | 53 | 40 | 78 | 10 | 43 |

It will be seen that Arabica has been grown without success at all the stations at which it was tried, and, indeed, in most cases the plants became so unhealthy that the attempt to acclimatise a variety that was obviously unsuited to local conditions was abandoned. Stenophylla, too, has given consistently meagre returns and only at one station (Aburi) has it yielded as well as Robusta. The two remaining varieties, Robusta and Liberica, have given by far the best returns ; Robusta has yielded more heavily at three out of the seven stations, and Liberica has prevailed at the remaining four. As in the case of the cacao variety trials, the yielding powers of the coffee varieties were in inverse proportion to the quality of their produce : the high quality Arabica (like Criollo) gave the lowest yield, and the low quality Liberica (like Amelonado) gave the highest.

## MEAN YIELDS IN FULL BEARING.

The mean yield of 2 to 3 cwt. of clean beans for Liberica and Robusta is undoubtedly low. This is due partly to the inclusion of the yields at Kibi station, where conditions were unsuitable, and of the yields at Asuansi station, where the returns were disappointing, due mainly to fungoid diseases. An examination of Tables I and II shows that while Robusta gave higher yields than Liberica during the early years of bearing, this superiority was not maintained. The comparative yield per acre at the five best stations for the period of full bearing was approximately 4 cwt. for Liberica, 3 cwt. for Robusta, and 2 cwt. for Stenophylla. But, in evaluating the comparative merits of Liberica and Robusta it must not be forgotten that Robusta yields coffee of better quality and flavour.

## RATIO OF BERRIES TO BEANS.

In addition to the yield records of the clean beans, the weights of fresh berries were also recorded. The ratio of berries to beans was calculated for each year's crop at each station, and the resultant figures were used as a check on the yields recorded. Doubtful yield figures were discarded, which explains the inclusion of question marks in Tables I to IV. Mean values for the ratio of berries to beans by weight are given in the following table :—

Pounds of Fresh Berries per pound Clean Beans (Husked).

| Variety. | Aburi. | Kumasi. | Wiawso. | Peki-Blengo. | Tarkwa. | Asuansi. | Kibi. | Mean. |
|---|---|---|---|---|---|---|---|---|
| Liberica .. | 10.1 | 11.4 | 8.3 | 8.7 | 9.1 | 10.3 | 9.8 | 9.7 |
| Robusta .. | 5.6 | 5.2 | 4.6 | 4.0 | 3.7 | 4.4 | 4.7 | 4.6 |
| Stenophylla | 5.5 | 5.3 | — | 5.3 | 4.5 | 4.4 | — | 5.0 |
| Arabica .. | — | — | — | 3.6 | 4.0 | 5.1 | — | 4.2 |

These figures show that Liberica berries have a much greater combined weight of skin, pulp and parchment than the other varieties, and that twice the weight of berries has to be harvested to secure the same weight of clean beans. Transport of berries from tree to pulping-place is a big item in harvesting costs, and the fact that, for the same weight of clean beans, this cost is twice as much for Liberica is another point in favour of Robusta.

## GROSS VALUE PER ACRE.

The coffee crop is considered to be one of the most promising crops for local conditions. There is no doubt that more coffee plants are being planted and that the imports of prepared coffee are increasing. The figures showing these facts are small compared with the statistics of our cacao industry or of the world's coffee crop, but there is no gainsaying the upward trend of the prospects for expanding the local coffee industry. At present prices (January, 1928, London prices of coffee 90s. cwt., cacao 40s. cwt.) the gross local value of the produce of an acre of coffee (282 lbs. at 8d. per lb. or 75s. cwt.) is £9 8s. as against £8 13s. 6d. for the produce of an acre of cacao (595* lbs. at 3½d. per lb. or 32s. 8d. cwt.). Of course coffee is a more laborious crop to handle, and there is no guarantee that the relative prices will endure, but it is obvious that the coffee crop merits much more detailed study locally than has been devoted to it in the past.

*Bulletin No. 4, Department of Agriculture ( page 7 ).

## INVESTIGATIONAL WORK.

Investigational work which is now being undertaken by the Department of Agriculture includes the following :—

(i) Monthly harvesting of the crop and recording of vegetative phenomena, flowering in particular, with the object of correlating seasonal yields with environmental conditions, and with meteorological data. To be recorded for all four varieties.

(ii) Recording of variations of size and weight of fresh berries and of clean beans, for use as in (i).

(iii) Recording of yields of individual trees, to provide material for breeding.

(iv) Reproduction by vegetative methods, especially grafting.

(v) Establishment of plots of improved strains at experiment farms.

(vi) Study of cultural operations, including effect of the following :—transplanting, shade, windbreaks, pruning, and drainage.

(vii) Study of pests and diseases, especially at Asuansi station.

(viii) Comparative farming costs of coffee and cacao.

(ix) Statistical study of world's coffee crop and world prices.

(x) Valuation of clean beans of each variety.

This list is by no means exhaustive, for it includes only the work to be undertaken immediately. The accumulation of precise data on the lines stated will provide material for an accurate estimation of the potentialities of the local coffee industry.

# TABLE No. I.

## LIBERICA.

Pounds of clean beans (husked) per acre.

| Station. | Aburi. | Kumasi. | Wiawso. | Peki-Blengo. | Tarkwa. | Asuansi. | Kibi. |
|---|---|---|---|---|---|---|---|
| Area in acres | 0.85 | 0.50 | 1.00 | 0.75 | 0.48 | 0.72 | 0.36 |
| Year established .. | 1912 | 1909 | 1916–17 | 1913 | 1912 | 1910 | 1912 |
| Yields. | | | | | | | |
| 1914 .. | — | 282 | — | — | — | (18) | — |
| 1915 .. | — | 232 | — | — | — | 40 | — |
| 1916 .. | — | 153 | — | — | (216) | 72 | (47) |
| 1917 .. | — | 236 | — | (17) | 445 | 119 | 50 |
| 1918 .. | — | 540 | — | 21 | 311 | 110 | 110 |
| 1919 .. | 202 | ? | — | 156 | 134 | 160 | 73 |
| 1920 .. | 112 | ? | (70) | 181 | 145 | 85 | 190 |
| 1921 .. | 291 | 384 | 154 | 33 | 220 | 79 | ? |
| 1922 .. | 279 | 342 | 664 | 241 | 204 | 386 | 46 |
| 1923 .. | 471 | 480 | ? | 548 | 260 | 331 | 50 |
| 1924 .. | 361 | 448 | 26 | 615 | 169 | 336 | 44 |
| 1925 .. | 474 | 450 | 644 | 771 | 307 | 289 | 64 |
| 1926 .. | 701 | 578 | — | — | — | 92 | — |
| 1927 .. | 691 | — | — | — | — | 347 | — |
| Mean yield .. | 398 | 375 | 372 | 321 | 244 | 188 | 78 |

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Note the increase of yield with age and the comparative steadiness of the yields from year to year. (Yields of early years, shown in brackets, are not included in the mean yields).

# TABLE No. II.

## ROBUSTA.

Pounds of clean beans (husked) per acre.

| Station. | Aburi. | Kumasi. | Wiawso. | Peki. Blengo. | Tarkwa. | Asuansi. | Kibi. |
|---|---|---|---|---|---|---|---|
| Area in acres | 0.55 | 0 50 | 0.77 | 0.75 | 1.07 | 0.87 | 0.35 |
| Year established .. | — | 1912 | 1916 | 1913 | 1904–7–12 | 1912 | 1911 |
| Yields. | | | | | | | |
| 1914 .. | — | — | — | — | — | — | — |
| 1915 .. | — | — | — | — | — | (6) | (94) |
| 1916 .. | — | (14) | — | — | 350 | (92) | 817 |
| 1917 .. | — | 127 | — | (67) | 666 | 167 | 97 |
| 1918 .. | — | 235 | (52) | 467 | 556 | 255 | 201 |
| 1919 .. | 193 | 274 | ? | 497 | 126 | 147 | 237 |
| 1920 .. | 22 | ? | 17 | 311 | 141 | 26 | 173 |
| 1921 .. | 280 | 338 | 68 | 49 | ? | 72 | 77 |
| 1922 .. | 15 | 305 | 66 | 341 | 235 | 241 | 251 |
| 1923 .. | 145 | 266 | ? | 209 | 252 | 122 | 33 |
| 1924 .. | 284 | 228 | 105 | 937 | 176 | 378 | 99 |
| 1925 .. | 202 | 190 | 624 | 311 | 703 | 240 | 75 |
| 1926 .. | 564 | 420 | — | — | — | 0 | — |
| 1927 .. | 291 | — | — | — | — | 80 | — |
| Mean yield .. | 222 | 265 | 189 | 390 | 356 | 157 | 296 |

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Note the high yields in the early years and the erratic yields in subsequent years. (Yields of early years, shown in brackets, are not included in the mean yields).

# TABLE No. III.

## STENOPHYLLA.

Pounds of clean beans (husked) per acre.

| Station. | Aburi. | Kumasi. | Wiawso. | Peki-Blengo. | Tarkwa. | Asuansi. | Kibi. |
|---|---|---|---|---|---|---|---|
| Area in acres | 0.35 | 0.50 | — | 0.75 | 1.07 | 0.18 | — |
| Year established .. | — | 1912 | — | 1913 | 1904–7–12 | 1912 | — |
| Yields. | | | | | | | |
| 1914 .. | — | — | | — | — | — | |
| 1915 .. | — | — | | — | 419 | — | |
| 1916 .. | — | (12) | | — | 115 | (67) | |
| 1917 .. | — | 2 | | 10 | 84 | 0 | |
| 1918 .. | — | 91 | | 0 | 110 | 239 | |
| 1919 .. | 220 | 101 | No | 1 | 62 | 33 | No returns. |
| 1920 .. | 91 | 92 | returns. | 36 | 155 | ? | |
| 1921 .. | 66 | 66 | | 13 | ? | 172 | |
| 1922 .. | 229 | 94 | | 209 | 230 | 17 | |
| 1923 .. | 357 | 266 | | 216 | 280 | 117 | |
| 1924 .. | 146 | 184 | | 51 | 77 | 161 | |
| 1925 .. | 254 | 380 | | 228 | 142 | 56 | |
| 1926 .. | 414 | 348 | | — | — | 100 | |
| 1927 .. | 254 | — | | — | — | 11 | |
| Mean yield .. | 226 | 162 | — | 94 | 167 | 91 | — |

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Yields low and erratic but improving with age. (Yields of early years, shown in brackets, are not included in the mean yields).

# TABLE No. IV.

## ARABICA.

Pounds of clean beans (husked) per acre.

| Station. | Aburi. | Kumasi. | Wiawso. | Peki-Blengo. | Tarkwa. | Asuansi. | Kibi. |
|---|---|---|---|---|---|---|---|
| Area in acres | | 1.00 | | 0.75 | 0.06 | 0.50 | 0.14 |
| Year established .. | | 1909 | | 1913 | 1912 | 1911 | 1912 |
| Yields. | | | | | | | |
| 1914 .. | | 0 | | — | — | 118 | — |
| 1915 .. | | 86 | | — | — | 84 | 14 |
| 1916 .. | | 12 | | — | ? | 32 | 15 |
| 1917 .. | | 55 | | 97 | ? | — | 1 |
| 1918 .. | | 2 | | 149 | ? | — | — |
| 1919 .. | | 59 | | 21 | 0 | — | — |
| 1920 .. | No | — | No | 0 | 0 | — | — |
| 1921 .. | returns. | — | returns. | 0 | ? | — | — |
| 1922 .. | | — | | — | ? | — | — |
| 1923 .. | | — | | — | 67 | — | — |
| 1924 .. | | — | | — | 58 | — | — |
| 1925 .. | | — | | — | 175 | — | — |
| 1926 .. | | — | | — | — | — | — |
| 1927 .. | | — | | — | — | — | — |
| Mean yield .. | — | 36 | — | 53 | 40 | 78 | 10 |
| | | | | | | | |
| | | | | 43 | | | |

The yields were consistently low. (Yields of early years, shown in brackets, are not included in the mean yields).

## PAPER No. XXIII.

# MOISTURE CONTENT AND MOULD IN COPRA.

By W. C. FISHLOCK.

The making of copra on a commercial scale was commenced at the Coconut Plantation, Atwabo, in October, 1927. The copra is made in the dryer described on page 111 of the 1927 Year-Book of the Department of Agriculture.

It early became evident that copra stored at the plantation was liable to become mouldy after a comparatively short time, and investigations were therefore started with a view to finding methods of preparation and storage whereby the occurrence of mould might be prevented.

At the commencement of these investigations it was thought that, by determining the moisture content of mouldy and clean copra, which had been in store approximately the same length of time, data might be obtained whereby a critical point of moisture content could be determined, i.e., a point in the moisture content below which moulds would not grow.

As the investigations proceeded it became apparent that this critical point, if it exists, is very indeterminate, and apparently cannot be fixed, since the investigations have shown that even over-dried copra is liable to mould when stored in a damp atmosphere, such as is prevalent at Atwabo.

It is practically certain that no initial amount of drying practicable in a commercial way will inhibit the eventual growth of certain moulds; those which can grow with a very small amount of moisture.

On the other hand, it is certain that the more dangerous moulds—*Aspergillus niger* and *Aspergillus flavus*, only grow on copra that has not been sufficiently dried. Neither of these species has been found on dry copra at the plantation. It was also thought that copra in store, though initially well dried, absorbed sufficient moisture in the course of time to enable moulds to grow on it.

While there is no doubt that copra in store does absorb moisture (vide Table III), it is very doubtful whether it would absorb sufficient moisture to enable *Aspergillus niger* or *Aspergillus flavus* to grow on it.

Well dried copra kept in bags in the store on the plantation became 100 per cent. mouldy in periods ranging from 36 to 61 days, but the mould on it was certainly neither *Aspergillus niger* or *Aspergillus flavus*; it was a greyish-green mould on the surface only, and would easily be brushed off. The dry meat below was perfectly sound.

Parker and Yates, in their paper on "Copra and Coconut Oil." (The Phillipine Journal of Science, Vol. XII, section A. No. 2, March 1917) state that "*Aspergillus niger* Van Teigh (black mould).....plays a more important part than does *Rhizopus* sp. (white mould) but a far less important one than does *Aspergillus flavus* (brown mould).....It only appears on copra that contains at least 12 per cent. of moisture.

The same writers, in the same paper, state the following of *Aspergillus flavus* :—

> "*Aspergillus flavus* Link (brown mould). This species of Aspergillus is the mould that plays the most important part in the destruction of oil in copra. It is the brown mould that is usually seen on badly moulded copra. It occurs on copra with a moisture content of from seven to eight per cent."

Of the green mould they write as follows :—

> "*Penicillium glaucum* Link (green mould). This is the common green mould often seen upon copra. It grows well on copra containing a very low percentage of water. Analyses show that this mould destroys hardly any of the oil in the copra. A growth of Penicillium alone may be said almost to serve as an indicator of good copra, because it grows at a moisture content of between five and seven per cent., causes practically no loss in the oil content, and produces very little free acid."

In view of the extracts quoted, we may say that there is no cause for alarm regarding moulds on the copra made at the plantation.

The moisture content of fresh kernel from nuts grown on the plantation is in some doubt at the time of writing. The writer obtained the following results from three tests, 42.0 per cent. 43.6 per cent. and 40.0 per cent.; while a test made at Aburi gave 43.6 per cent. All these figures are probably too low, since the loss in weight in drying 73,110 lbs. kernel to copra amounted to 44.61 per cent. It is probable that a certain amount of that loss in weight is due to the loss of very small, broken copra, etc., but loss from these causes is certainly small. Further, the loss in drying 2,400 lbs. kernel to copra in 24 lots, in trays specially made to prevent loss, amounted to 42.96 per cent. It is, however, reasonably certain that the moisture content of copra produced in the dryer at the plantation is below the seven per cent. stated by Parker and Yates as the minimum at which dangerous moulds can grow.

Details of certain moisture determinations made at the plantation are shown in Table I.

## TABLE I.

DETERMINATIONS OF MOISTURE CONTENT OF COPRA AND KERNEL CARRIED OUT AT THE COCONUT PLANTATION, ATWABO.

| No. of determination. | Date determination made. | No. of lot from which sample was taken. | Lot from which sample taken reduced from 100 lbs. to — lb. in drying. | Moisture content at time of determination. | Date lot taken from dryer. | Remarks. |
|---|---|---|---|---|---|---|
| 1 | 1-7-28 | — | — | 42.0% | — | Fresh kernel. |
| 2 | 2-7-28 | — | — | 7.1% | — | Copra made in April, 1928, not mouldy. |
| 3 | 2-7-28 | — | — | 6.7% | — | Copra made in April, 1928, mouldy. |
| 4 | 3-7-28 | 8 | 56 | 4.9% | 2-7-28 | |
| 5 | 10-7-28 | 9 | 57 | 7.4% | 8-7-28 | |
| 6 | 13-7-28 | — | — | 7.3% | — | Mouldy copra. |
| 7 | 15-7-28 | 3 | 61 | 7.9% | 7-6-28 | Mouldy copra. |
| 8 | 15-7-28 | 3 | 61 | 7.1% | 7-6-28 | Not mouldy. |
| 9 | 16-7-28 | 4 | 59 | 7.7% | 14-6-28 | Mouldy copra. |
| 10 | 18-7-28 | 4 | 59 | 7.0% | 14-6-28 | Not mouldy. |
| 11 | 18-7-28 | — | — | 26.5% | — | Coconut kernel which had been exposed in shade from 14th to 18th July. Aspergillus niger and other destructive fungi present. |
| 12 | 20-7-28 | 3 | 61 | 7.6% | 7-6-28 | Toluene used as a reagent in this case, in the others Xylene used. |
| 13 | 21-7-28 | — | — | 43.6% | — | Fresh kernel. |
| 14 | 26-7-28 | — | — | 40.0% | — | Fresh kernel. |

## THE INCIDENCE OF MOULDS ON LOTS OF COPRA STORED IN BAGS.

The copra obtained from the 24 lots of kernel dried in specially made trays and treated in the manner described above was bagged separately and stored in a building with concrete walls and floor and an asbestos sheet roof. The bags were kept on palm stick grids, with an air space between the bags and the concrete floor. The bags were examined periodically, and notes made as to the occurrence of mould. It has been found that in time all the copra becomes mouldy ; it is merely a question of time. Reference to Table II will show that some of these lots were dried to the extent of losing 45.5 of their original weight as fresh kernel. It is safe to assume that all the loss was moisture, since precautions were taken to prevent loss in other ways.

Assuming that the moisture content of the kernel from which these lots of copra was made was as high as 48 per cent. (Parker and Yates, in their article already quoted, give a series of five determinations of the water content of fresh kernel, the average of the five being 48 per cent. moisture) this would indicate that Lot 18 contained only 2.5 per cent. of moisture at the time it was taken from the dryer.

Records of the experiment so far as it has been carried out, are shown in Table II of this paper.

Certain discrepancies in weight will be noticed, i.e., some lots appear to have lost weight in storage, this is due to samples for various other tests having been taken from them. The experiment will be continued till definite results are obtained.

## TREATMENT OF KERNEL WITH A VIEW TO THE PREVENTION OF MOULD.

Sulphur dioxide is largely used as a treatment for deciduous fruits, such as apricots, peaches, etc., prior to drying them, the object in view being the prevention of mould.

The Assistant Director of Agriculture suggested that this treatment should be tried on coconut kernel ; the suggestion was adopted and trials were made.

A box of roughly four cubic feet capacity was made, fitted with a moveable lid and trays, and made fairly tight, but not air tight, as there must be sufficient ventilation to allow the sulphur to burn. Two expanded metal trays were fitted to it.

# TABLE II.

## Incidence of Mould on Stored Copra.

| Trial Number. | Days Dried. | Commercial Copra obtained per 100 kernel. lbs. | Second weighing. | | Third weighing. | | Fourth weighing. | | Second weighing. | | Third weighing. | | Fourth. weighing | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Days in Store. | Weight in lbs. | Total days in Store | Weight in lbs. | Total days in Store. | Weight in lbs. | Days in Store. | Weight Mouldy in lbs. | Total days in Store. | Weight Mouldy in lbs. | Total days in Store. | Weight Mouldy in lbs. |
| 2 | 4 | 59½ | 43 | 60½ | 57 | — | — | — | 43 | 56½ | 57 | All | — | — |
| 3 | 4 | 61 | 40 | 60½ | — | — | — | — | 40 | All | — | — | — | — |
| 4 | 4 | 59 | 33 | 57½ | 47 | — | — | — | 33 | 38½ | 47 | All | — | — |
| 5 | 4 | 58½ | 29 | 59 | 43 | — | 57 | 58¾ | 29 | 26¼ | 43 | 54¼ | 57 | All |
| 6 | 4 | 58 | 26 | 59¾ | 40 | — | 50 | 59½ | 26 | 31¾ | 40 | 51½ | 54 | All |
| 7 | 5 | 60½ | 22 | 60 | 36 | — | — | — | 22 | 54 | 36 | All | — | — |
| 8 | 8 | 55 | 15 | 56¼ | 29 | — | 43 | 57¼ | 15 | 1¼ | 29 | 3 | 43 | 17½ |
| 9 | 4 | 57 | 10 | 57 | 24 | — | 38 | 58 | 10 | 1¼ | 24 | 6 | 38 | 16¾ |
| 10 | 5 | 57½ | 7 | 57 | 21 | — | 35 | 56½ | 7 | Nil | 21 | 13 | 35 | 21½ |
| 11 | 4 | 57 | 5 | 57¾ | 19 | — | 33 | 57 | 5 | Nil | 19 | Nil | 33 | Nil |
| 12 | 4 | 55½ | 4 | 55½ | 18 | 55½ | — | — | 4 | Nil | 18 | 12½ | — | — |
| 13 | 4 | 59 | 7 | — | 21 | 59 | — | — | 7 | Nil | 21 | 1 | — | — |
| 14 | 4 | 57¾ | 7 | — | 21 | 57¾ | — | — | 7 | Nil | 21 | 6¼ | — | — |
| 15 | 5 | 56 | 3 | — | 17 | 57 | — | — | 3 | Nil | 17 | Nil | — | — |
| 16 | 5 | 56 | 3 | — | 17 | 57 | — | — | 3 | Nil | 17 | Nil | — | — |
| 17 | 4 | 55 | — | — | 14 | 56 | — | — | — | Nil | 14 | Nil | — | — |
| 18 | 4 | 54½ | — | — | 14 | 55½ | — | — | — | Nil | 14 | Nil | — | — |
| 19 | 4 | 53½ | 11 | 54½ | 25 | 54½ | — | — | 11 | Nil | 25 | Nil | — | — |
| 20 | 4 | 54 | 11 | 54¾ | 25 | 54¾ | — | — | 11 | Nil | 25 | Nil | — | — |
| 21 | 4 | 55 | 7 | 55½ | 21 | — | — | — | 7 | Nil | 21 | — | — | — |
| 22 | 4 | 54½ | 7 | 55¼ | — | — | — | — | 7 | Nil | — | — | — | — |
| 23 | 5 | 55½ | 3 | 56¼ | — | — | — | — | 3 | Nil | — | — | — | — |
| 24 | 5 | 56½ | 3 | 57 | — | — | — | — | 3 | Nil | — | — | — | — |

In the first trial two five pound lots of kernel as ordinarily cut from the nuts, were taken, one lot was washed in sea water and drained and then placed on the lower of the two metal trays, with the inner or white side of the kernel downward. The other lot was not washed, and was placed in the upper tray. The lid was replaced, and about half a pound of sulphur was burnt in a metal dish in the bottom of the box ; a hole, large enough for the passage of the dish, had been cut in the side of the box. The kernel was allowed to remain in the fumes of the sulphur 36 hours. It was then taken out and exposed to the air in a building with palm stick sides and a thatch roof, in conditions very suitable for the growth of mould. The kernel kept perfectly well in these conditions for ten days. A five pound lot of kernel, not treated in any way, and exposed alongside the two treated lots, became a mass of mould in three days. Results of this method of treatment are shown in Lots 1c, 2c and 3c.

## SUMMARY OF RESULTS OF TREATING KERNEL WITH SULPHUR DIOXIDE.

The full table of examinations of the kernel after treatment is too long to insert in full ; results are therefore summarised in the following form :—

Lot 1. A. Washed in sea water and then treated with sulphur dioxide 36 hours (½ lb. sulphur burnt in a box o about four cubic feet capacity). Exposed in shade on July 25. Kept perfectly clean and white till August 4 (10 days), when mould began to appear. By August 6 all was mouldy.

Lot 1. B. Not washed. Treated with sulphur dioxide 36 hours. Exposed in shade as above. Kept perfectly good till August 4 (10 days), when mould began to appear. On August 6 all but one piece was mouldy.

Lot 1. C. Not treated in any way. Exposed in shade as A. and B. on July 25th. On July 27th (two days) white mould (Rhizopus sp.) appeared. On the 28th (three days) all was mouldy, and on the 30th (five days) all was a mass of mould.

Lot 2. A. (Half nuts in shell). Washed in sea water and treated with sulphur dioxide 18 hours. Exposed in shade July 28th. Kept perfectly till August 4th (seven days), when slight mould was seen on three pieces out of 16. On August 6th all was mouldy.

Lot 2. B. Not washed. Treated with sulphur dioxide 18 hours. Exposed as above, and on the same date. Faint traces of mould appeared on three pieces out of 16 on August 4th (seven days), and on the 6th all was mouldy.

Lot 2. C. Not treated in any way. Exposed as above. On July 30th (2 days) 15 out of 16 pieces were mouldy, and on August 2nd (five days), all was a mass of mould.

Lot 3. A. (Half nuts in shell). Washed in sea water and treated with sulphur dioxide 18 hours. Exposed to sun and air on July 31st. Kept perfectly well till August 8th, when slight mould was seen on one piece. On August 10th 37 pieces were perfectly clean and three pieces mouldy.

Lot 3. B. Treated with sulphur dioxide only. Exposed as above. All kept perfectly clean and good till August 10th.

Lot 3. C. Not treated in any way. Exposed as above. On August 2nd 10 pieces were discolored and one piece mouldy. On August 6th 32 were mouldy and eight clean, and on August 10th 34 were mouldy and six clean.

NOTE.—The half nuts in Lot 3 A, B, and C, were exposed on a stand in the open air, they were not put in at night or when rain fell, being merely inverted on those occasions.

These experiments indicate that perfectly good copra, free from mould, can be prepared by this method of treating the kernel with sulphur dioxide and then drying in the sun and air.

## INCREASE IN WEIGHT OF STORED COPRA, PRESUMABLY BY THE ABSORPTION OF MOISTURE.

For some time it had been thought that well dried copra increased in weight during storage, and certain tests were carried out with a view to obtaining information on this point.

In the " Harmattan " season, January, 1928, two bags of well-dried copra, one first grade and one second grade, were carefully weighed and put aside in the store. They were re-weighed after an interval, and a note made of the increase in weight. Bag No. 1, first grade, gained 2 per cent. in weight in 67 days. Bag No. 2, second grade, gained 2 per cent. in weight in 62 days.

In July other bags of well dried copra were carefully weighed, and re-weighed after an interval. In each case there was an increase in weight, varying from 2.82 per cent. in 32 days to 1.16 per cent. in 8 days. In the latter case the loss of weight in original drying to copra was 43.5 per cent.

Results are shown in Table III.

## TABLE III.

### Showing increase in Weight of Stored Copra.

| No. of Test. | Date of first weighing. | Original weight. lbs. | Percentage loss in drying from kernel to Copra. | Date of re-weighing. | Interval between weighing days. | Weight on re-weighing lbs. | Percentage increase. |
|---|---|---|---|---|---|---|---|
| 1 | 6–1–28 | 100 | Not recorded | 14–3–28 | 67 | 102 | 2.0 |
| 2 | 6–1–28 | 100 | do. | 9–3–28 | 62 | 102 | 2.0 |
| 3 | 7–7–28 | 100 | do. | 9–8–28 | 32 | 102½ | 2.5 |
| 4 | 7–7–28 | 69 | do. | 9–8–28 | 32 | 71 | 2.90 |
| 5 | 10–7–28 | 1,008 | do. | 9–8–28 | 29 | 1,020 | 1.19 |
| 6 | 12–7–28 | 600 | 47.5 | 9–8–28 | 27 | 609 | 1.5 |
| 7 | 28–7–28 | 112 | 43.1 | 9–8–28 | 11 | 114 | 1.80 |
| 8 | 31–7–28 | 300 | 45.3 | 9–8–28 | 8 | 303½ | 1.17 |
| | | | | | | | |

It is therefore clear that well dried copra does absorb moisture, but, as stated earlier in the paper, it is very doubtful whether it would absorb sufficient moisture to enable the dangerous mould to grow on it. This point will, however, be decided by a continuation of these experiments.

## PAPER No. XXIV.

# INVESTIGATIONS IN VARIETIES OF COCONUTS AND COMPARATIVE YIELDS OF KERNELS AND COPRA.

By W. C. FISHLOCK.

The investigations described in this paper were carried out at the Coconut Plantation, Atwabo. They were aimed at securing definite information on certain matters connected with the cultivation of coconut palms and the making of copra.

The intention of Government in establishing the Plantation was that it should, by actual demonstration, arouse interest in a coconut and copra industry in Eastern and Western Nzima.

The investigations described in this paper may be said to be the commencement of efforts to gain definite and useful information for the benefit of what will, in all probability, become a very important and valuable industry in the Nzima country.

The investigations make no pretensions to finality; they are merely the beginning of attempts to accumulate knowledge on the subject of coconuts and copra as applicable to this part of the country. They may also have a use as indicating lines for future investigations.

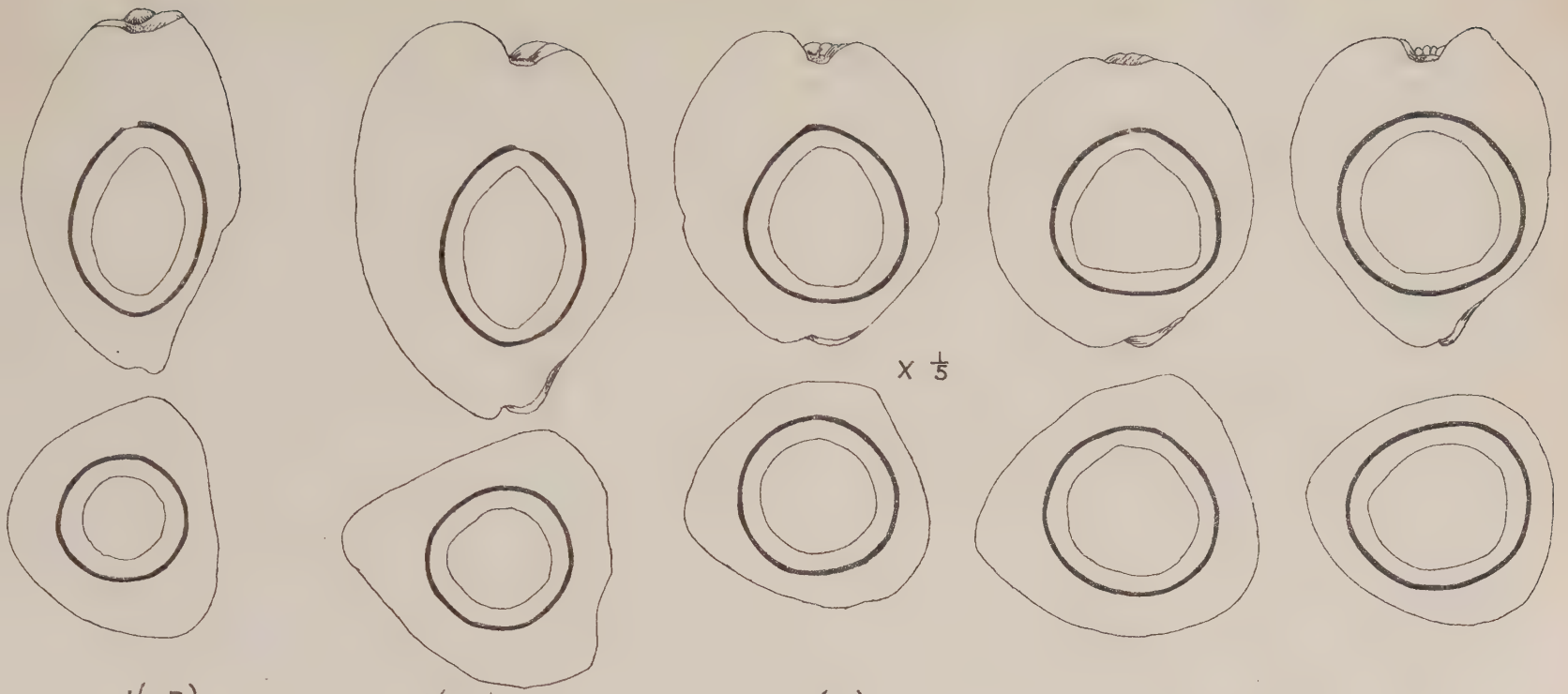
## YIELDS OF DIFFERENT TYPES OF NUTS.

The economic life of a coconut palm is probably 40 to 50 years. It is, therefore, obvious that only the best varieties available should be planted.

The object in view in planting coconut palms may be either the production of nuts for sale as such, or the production of copra (the dried kernel, or "meat" of the nut). In the first case it is desirable to plant a variety yielding nuts which "gauge" well, since nuts are graded according to size; those four inches and over in diameter selling as "Selects," and those under four inches in diameter selling as "Culls," with a discrimination in price.

The object in view at Atwabo is the production of copra. Size of nut is therefore not the only consideration. The amount of kernel, and consequently copra, produced by the nuts from any

PLATE LII.




DIAGRAMS OF TYPES OF COCONUTS.

Survey H.Q. Accra, 1929.

ndividual palm depends on several factors. Among these are ; size of nuts, thickness of kernel, number of nuts produced per annum, and, probably, moisture content of the fresh kernel. The latter is known to vary in other countries, and there is no reason to suppose it does not vary here.

It will be seen that a palm bearing a large number of comparatively small nuts, with thick kernel and low water content of the fresh kernel, may produce as much copra per year as, or more than, a palm bearing larger, but fewer and inferior nuts.

With the object of gaining definite information on some of these points, and with a view to the selection of a good type or types for propagation purposes, five types of nuts were selected from among the many nuts with varying characters to be found growing at the plantation. It will, of course, be understood that the nuts selected are merely types ; they are not fixed varieties, and that all intermediate characters between the types are to be found at the Plantation.

The types have been designated " A," " B," " C," " D " and " E." The Assistant Director of Agriculture has kindly made drawings of the types for illustration. They are shown on Plate LII.

It was found that little reliance could be placed on the exterior appearance and shape of the fruit as an indication of the type of nut within the husk. One or more nuts from each palm examined were therefore husked, and each husked nut compared with the type nuts in order to determine whether it conformed with one or other of the types or not. The majority of the nuts so husked conformed with none of the types and were therefore rejected for the purpose in view.

Having decided that the nuts borne by any given palm conformed with one or other of the types, the palm was marked with the appropriate letter, for future reference and collection of nuts.

Nuts of the types selected have been dealt with in lots of one thousand nuts. In each case the thousand nuts comprising the lot were made into a heap, and one hundred nuts were then taken from the heap at random, husked and gauged. The husked and gauged nuts were broken and the kernel removed and weighed separately. The remaining nine hundred in each lot were split by axing them in the usual way and the kernel removed and weighed. The dry copra obtained from each lot was also weighed separately. Results are shown in tabular form.

Table I. Shewing results obtained from five selected types of Nuts.

TABLE I.

| Type of Nut. | Number dealt with. | Average diameter of nuts, inches. | Weight of Kernel obtained. lbs. | Weight of Copra obtained. lbs. | Number of Nuts required to produce one ton of | |
|---|---|---|---|---|---|---|
| | | | | | Kernel. | Copra. |
| "A" .. .. | 5,000 | $4\frac{1}{4}$ | 3,683 | 2,021 | 3,042 | 5,541 |
| "B" .. .. | 5,000 | $4\frac{3}{8}$ | 3,797 | 2,128 | 2,950 | 5,263 |
| "C" .. .. | 1,000 | $4\frac{3}{8}$ | 765 | 425 | 2,928 | 5,270 |
| "D" .. .. | 5,000 | $3\frac{13}{16}$ | 3,365 | 1,874 | 3,329 | 5,976 |
| "E" .. .. | 5,000 | $4\frac{3}{8}$ | 3,833 | 2,133 | 2,922 | 5,250 |

Each of the types shows a better yield than the average yield of copra on the Plantation, which is 6,358 nuts per ton of copra. The gain in nuts per ton of copra shown by the respective types is as follows :—

| | | |
|---|---|---|
| "A" Type | 817 | nuts per ton of copra. |
| "B" ,, | 1,095 | ,, ,, ,, ,, ,, |
| "C" ,, | 1,087 | ,, ,, ,, ,, ,, |
| "D" ,, | 382 | ,, ,, ,, ,, ,, |
| "E" ,, | 1,108 | ,, ,, ,, ,, ,, |

"B" type, which, so far as the investigations have gone, is the most abundant on the Plantation, is certainly worthy of further investigation.

## THE RATIO OF DRY COPRA TO KERNEL.

In order to obtain information as to the amount of well dried copra obtainable from average kernel a series of experiments were planned and carried out. Specially made trays, with mosquito gauze bottoms to prevent waste as much as possible, were used in the dryer for these experiments.

The kernel was dealt with in 100 lb. lots. The lots were dried, usually one lot at a time, simultaneously with kernel being dried in the ordinary way. The temperature of the air at the base of the exhaust shaft of the dryer was usually about 140° F. during the time the kernel was drying. The kernel was, in most cases, weighed at the expiration of each 24 hours in the dryer, and was kept in the dryer in most cases 72 hours. In no case was it kept in less than this time. In five cases it was kept in 96 hours. The results of drying 24 lots in this way are shown in Table II.

## TABLE II.

Records of the drying of 24 lots of kernel, commencing May 29, 1928. Initial weight of kernel 100 lbs. in each case.

| Lot No. | Date put in Dryer. | Weight after—hours in dryer. | | | | |
|---|---|---|---|---|---|---|
| | | 24 | 48 | 72 | 96 | Final Weight. |
| 1 | May 29 .. .. | 63 | 59½ | 58½ | — | 58½ |
| 2 | June 1 .. .. | 64½ | 60 | 59½ | — | 59½ |
| 3 | „ 4 .. .. | 68 | 62½ | 61 | — | 61 |
| 4 | „ 11 .. .. | 65 | 60 | 59 | — | 59 |
| 5 | „ 15 .. .. | 64½ | 59½ | 58½ | — | 58½ |
| 6 | „ 18 .. .. | 62½ | 58½ | 58 | — | 58 |
| 7 | „ 21 .. .. | 63 | 60 | 60 | — | 60 |
| 8 | „ 25 .. .. | 64½ | 60½ | 56 | — | 56 |
| 9 | July 5 .. .. | 60 | 58½ | 57 | — | 57 |
| 10 | „ 6 .. .. | 87 | 68½ | 60½ | 57 | 57 |
| 11 | „ 9 .. .. | 61 | 58 | 57 | — | 57 |
| 12 | „ 10 .. .. | 71 | 59½ | 55½ | — | 55½ |
| 13 | „ 21 .. .. | — | — | 59 | — | 59 |
| 14 | „ 21 .. .. | — | — | 57¾ | — | 57¾ |
| 15 | „ 24 .. .. | — | 58 | 57¼ | — | 57¼ |
| 16 | „ 24 .. .. | — | 61 | 59½ | — | 59½ |
| 17 | „ 28 .. .. | 61½ | 56 | 55 | — | 55 |
| 18 | „ 28 .. .. | 84 | 59 | 54½ | — | 54½ |
| 19 | „ 31 .. .. | 65 | 58 | 53½ | — | 53½ |
| 20 | „ 31 .. .. | 68 | 58 | 54 | — | 54 |
| 21 | Aug. 3 .. .. | 87 | 65½ | 59½ | 55 | 55 |
| 22 | „ 3 .. .. | 81½ | 61 | 55 | 54½ | 54½ |
| 23 | „ 7 .. .. | 75½ | 61 | 58½ | 56½ | 56½ |
| 24 | „ 7 .. .. | 84½ | 63½ | 58½ | 55½ | 55½ |

Mean 57.04 lbs. copra per 100 lbs. kernel.

For the purpose of comparison the following data regarding that part of crop in which the nuts collected were counted is given :—

| | |
|---|---|
| Number of Nuts counted .. .. .. .. | 119,778 |
| No. useless .. .. .. .. .. | 4,817 |
| No. used for copra .. .. .. .. .. | 114,961 |
| Weight of kernel obtained, lbs. .. .. .. | 73,100 |
| Weight of copra obtained, lbs. .. .. .. | 40,502 |
| No. of nuts per ton of kernel .. .. .. | 3,521 |
| No. of nuts per ton of copra .. .. .. | 6,358 |
| Ratio of kernel to nuts .. .. .. | 63.57 per cent. |
| Ratio of copra to nuts .. .. .. | 35.22 „ „ |
| Ratio of copra to kernel .. .. .. | 55.39 „ „ |

In other words, each 100 average nuts may be expected to yield 63½ lbs. kernel and 35¼ lbs. dry copra, and each 100 lbs. kernel 55.39 lbs. dry copra.

PAPER No. XXV.

# TRIALS OF CERTAIN METHODS OF SAMPLING COPRA.

By I. L. SCOTT.

The local copra industry is in its infancy. The annual export does not exceed 2,000 tons and there is no reason why it should not some day develop to a figure of which that is a mere fraction. In the meantime, however, the most pressing problem which faces the industry is the inferior quality of the finished product. This is not a surprising state of affairs since the crop is in the hands of peasant farmers who, despite their energy, are severely handicapped by the fact that they are illiterate and are working on a product the essentials of which are unknown to them.

The trade as a whole has come to recognise its own shortcomings and at a meeting of the Keta-Ada District Agricultural Committee, held at Keta in June 1928, the whole question of quality was discussed. It was agreed that the best initial move in any attempt to improve and equalise the quality of the product was to ask Government to introduce some system of beach inspection analogous to the voluntary one obtaining in the cacao trade. Government has decided to comply with this request and it is the purpose of this paper to describe the means taken to found a workable basis for copra inspection.

## AIMS OF INSPECTION.

The ultimate success of such a scheme will depend on collaboration between this Department and the Copra industry. The function of the Department of Agriculture is straightforward namely, to give a report to every merchant on every consignment which he sends out of the country. The ideals to be aimed at may be summed up under three headings :—

1. The report must be at once accurate and descriptive.
2. Its data must be obtained with the least possible interference with the movement of the product and the convenience of the exporter.
3. Although the data must be of maximum accuracy they muct be obtained with the minimum of expenditure and labour.

All experiments were carried out with those arms in view.

COPRA ON A DRYING TRAY—AVERAGE SAMPLE.

## EXPERIENCE GAINED FROM CACAO INSPECTION.

The result of two years' work on cacao inspection leaves no doubt as to the general mathematical principles to be followed in the adaptation. It has been demonstrated that the examination of the square root of the number of bags in a consignment gives a sufficiently accurate picture of the quality of the consignment as a whole. (Department of Agriculture Year Book 1927, pp.45–57).

The average shipment made at Keta is one hundred tons or sixteen hundred bags of copra. The number of shipments of less than twenty-five tons or four hundred bags is negligible and this size of consignment may be taken as the minimum size to be examined. That is to say, the smallest sample which, when taken, one from each of twenty bags, and has its figures totalled, gives an accurate average, is the sample to be desired. The problem therefore resolves itself into :—

1. Method of determining the percentage.
2. Size of Sample.
3. Method of obtaining the sample.

Questions Nos. 2 and 3 are interdependent and on the result of investigations into No. 2 hangs very much the answer to No. 3.

## METHOD OF DETERMINING PERCENTAGE.

At this point of the problem the resemblance between cacao and copra as sampling media comes to an end. Cacao beans are small and regular in size and weight. The average cacao bean weighs approximately one gram and the variation from this mean are negligible. In a paper written by Mr. Beckett (Department of Agriculture YearBook 1927, pp. 58–61) it was proved that a count of defects in cacao beans gives a percentage similar to that obtained by weighing them. The very appearance of copra would seem to preclude the simple method of count for obtaining percentages. Plate No. LIII is a typical specimen of local copra. The extreme irregularity in size and shape will be noted. Actually pieces vary in size from fragments of less than $\frac{1}{2}$ inch in length and breadth to pieces of seven inches long by three inches broad.

In shape the variety is just as great. Any attempts to correlate weight and count were unproductive of results and it was realised that count must be left out as a process of analysis.

## SIZE OF SAMPLE.

A series of experiments was carried out with the object of finding the smallest sample capable of giving accurate results. The following is a description of these experiments.

### Experiment 1.

There are four defects which affect the commercial value of copra. They are :—moulds, insect larvæ, immature pieces and

extraneous matter. A bag of copra containing 140 lbs. was bulked on the floor. Four separate weights were taken from the whole :—

1. 19 lbs. 10.5 oz. or 14.1%
2. 19 ,, 5 ,, ,, 13.8%
3. 19 ,, 12 ,, ,, 14.1%
4. 19 ,, 15 ,, ,, 14.3%

No. 1 was dyed Black, No. 2 Green, No. 3 Red and No. 4 Maroon. They were replaced amongst the bulk and the whole thoroughly remixed. The weight of copra might then be considered as a bag containing a certain known percentage of defects.

A sample weighing 1 lb. 9 ozs. or 25 ozs. was tested. The particular weight was chosen because of the ease with which it could be expressed as a percentage. The four different colours were removed from the sample and weighed separately. The figures having been noted the sample was returned to the bulk and the whole thoroughly remixed before another sample was taken. The experiment was repeated twenty times and might be considered equivalent to the removing of twenty samples weighing 25 ozs. each, one from each of twenty bags of copra of known quality.

The table below gives a summary of the results :—

| Sample No. | Black. | Green. | Red. | Maroon. |
|---|---|---|---|---|
| 1 .. .. .. | 3.6 | 2.1 | 7.5 | 3.1 |
| 2 .. .. .. | 4.3 | 5.5 | 5.3 | 3.8 |
| 3 .. .. .. | 3.8 | 4.8 | 5.8 | 5.4 |
| 4 .. .. .. | 7.5 | 2.0 | 6.5 | 5.5 |
| 5 .. .. .. | 3.3 | 2.0 | 7.5 | 4.0 |
| 6 .. .. .. | 3.8 | 1.0 | 8.8 | 2.0 |
| 7 .. .. .. | 5.5 | 6.5 | 3.3 | 4.0 |
| 8 .. .. .. | 7.0 | 2.3 | 2.9 | 2.5 |
| 9 .. .. .. | 3.2 | 2.5 | 5.2 | 3.3 |
| 10 .. .. .. | 5.3 | 2.6 | 9.6 | 1.6 |
| 11 .. .. .. | 5.1 | 4.2 | 4.9 | 0.7 |
| 12 .. .. .. | 6.3 | 2.5 | 5.1 | 1.6 |
| 13 .. .. .. | 1.5 | 3.0 | 2.7 | 4.7 |
| 14 .. .. .. | 3.9 | 2.8 | 2.5 | 2.7 |
| 15 .. .. .. | 7.0 | 3.9 | 4.3 | 2.8 |
| 16 .. .. .. | 4.5 | 1.8 | 4.5 | 4.0 |
| 17 .. .. .. | 2.0 | 7.0 | 3.6 | 1.9 |
| 18 .. .. .. | 1.7 | 3.8 | 5.1 | 5.9 |
| 19 .. .. .. | 4.3 | 0.7 | 6.5 | 7.4 |
| 20 .. .. .. | 3.6 | 4.0 | 2.4 | 2.4 |
| Total .. .. .. | 87.2 | 65.0 | 104.0 | 69.3 |
| Average .. .. .. | 4.4 | 3.3 | 5.2 | 3.5 |
| Av. % .. .. .. | 17.6 | 13.2 | 20.8 | 14.0 |
| True % .. .. .. | 14.1 | 13.8 | 14.1 | 14.3 |
| Error .. .. .. | +3.5% | —0.6% | +6.7% | —0.3% |

The Red stained colour pieces show an error of 6.7%. The error in different defects to a certain extent offset one another but even with this advantage the total error over all defects comes to 9.3%. This is a very large error and forces one to the conclusion that a sample weighing 25 ozs. is too small.

**Experiment 2.**

The next sample to be tested was one weighing 50 ozs. or one double the weight used in experiment 1. The amount of labour to be saved by taking any weight intermediate between 25 ozs. and 50 ozs. would be negligible. Fifty ounces is a suitable figure for the calculation of percentage.

The bag used in experiment 1 was again used. The table below gives a summary of the results :—

| Sample No. | Black. | Green. | Red. | Maroon. |
|---|---|---|---|---|
| 1 .. .. .. | 8.9 | 3.9 | 6.5 | 7.3 |
| 2 .. .. .. | 6.3 | 6.5 | 9.5 | 3.9 |
| 3 .. .. .. | 10.0 | 6.3 | 9.4 | 8.4 |
| 4 .. .. .. | 11.3 | 5.5 | 4.2 | 10.9 |
| 5 .. .. .. | 3.4 | 5.7 | 7.9 | 5.3 |
| 6 .. .. .. | 10.5 | 2.3 | 3.1 | 13.1 |
| 7 .. .. .. | 6.3 | 7.6 | 8.0 | 6.8 |
| 8 .. .. .. | 7.8 | 4.5 | 9.3 | 7.0 |
| 9 .. .. .. | 8.5 | 9.5 | 6.1 | 10.3 |
| 10 .. .. .. | 5.8 | 5.5 | 8.1 | 6.0 |
| 11 .. .. .. | 10.0 | 8.4 | 3.7 | 6.9 |
| 12 .. .. .. | 7.5 | 12.9 | 2.7 | 7.7 |
| 13 .. .. .. | 6.0 | 4.5 | 5.2 | 4.0 |
| 14 .. .. .. | 5.0 | 8.5 | 9.2 | 6.7 |
| 15 .. .. .. | 6.5 | 8.1 | 6.7 | 10.8 |
| 16 .. .. .. | 8.3 | 8.2 | 7.7 | 3.3 |
| 17 .. .. .. | 10.8 | 3.3 | 9.4 | 2.7 |
| 18 .. .. .. | 9.2 | 6.3 | 6.5 | 6.3 |
| 19 .. .. .. | 7.8 | 8.6 | 6.6 | 10.0 |
| 20 .. .. .. | 8.8 | 6.3 | 7.0 | 8.5 |
| Total .. .. | 158.7 | 132.4 | 136.8 | 145.9 |
| Average .. .. .. | 7.9 | 6.6 | 6.8 | 7.3 |
| Av. % .. .. .. | 15.8 | 13.2 | 13.6 | 14.6 |
| True% .. .. .. | 14.1 | 13.8 | 14.1 | 14.3 |
| Error .. .. .. | +1.7% | —0.6% | —0.5% | +0.3% |

The black painted copra shows the largest error namely 1.7%. The error in different defects offset one another and the total error

over all defects is 0.9%. Such errors are for all purposes negligible and the sample may be so far considered satisfactory.

It only remains to put this weight of sample to further tests.

**Experiment 3.**

Another bag of copra containing 140 lbs. of copra was treated similarly to bag No. 1, except that the percentages of Black, Green, Red and Maroon were each made to weigh 7.0% of the total weight. A sample weighing 50 ozs. was again used with the result shown below :—

| Sample No. | Black. | Green. | Red. | Maroon. |
|---|---|---|---|---|
| 1 .. .. .. | 1.5 | 4.0 | 5.9 | 1.6 |
| 2 .. .. .. | 4.4 | 3.4 | 3.6 | 5.4 |
| 3 .. .. .. | 3.9 | 2.8 | 2.8 | 5.5 |
| 4 .. .. .. | 1.9 | 5.6 | 6.0 | 4.2 |
| 5 .. .. .. | 1.0 | 0.7 | 5.0 | 2.3 |
| 6 .. .. .. | 3.7 | 6.3 | 4.5 | 1.9 |
| 7 .. .. .. | 2.5 | 2.4 | 5.5 | 2.5 |
| 8 .. .. .. | 4.3 | 3.2 | 4.7 | 4.5 |
| 9 .. .. .. | 3.7 | 1.6 | 1.0 | 2.6 |
| 10 .. .. .. | 2.9 | 4.3 | 3.0 | 5.8 |
| 11 .. .. .. | 0.9 | 5.6 | 4.8 | 5.7 |
| 12 .. .. .. | 5.0 | 3.2 | 4.4 | 2.5 |
| 13 .. .. .. | 7.0 | 3.3 | 0.9 | 3.2 |
| 14 .. .. .. | 3.6 | 4.5 | 5.2 | 5.5 |
| 15 .. .. .. | 6.4 | 3.6 | 2.2 | 4.3 |
| 16 .. .. .. | 1.8 | 1.4 | 4.7 | 3.6 |
| 17 .. .. .. | 1.2 | 7.2 | 2.7 | 1.8 |
| 18 .. .. .. | 3.1 | 3.5 | 3.2 | 10.1 |
| 19 .. .. .. | 7.4 | 5.1 | 2.7 | 2.3 |
| 20 .. .. .. | 3.2 | 3.6 | 3.2 | 6.5 |
| Total .. .. | 69.4 | 75.3 | 76.0 | 81.8 |
| Average .. .. .. | 3.5 | 3.8 | 3.8 | 4.1 |
| Av. % .. .. .. | 7.0 | 7.6 | 7.6 | 8.2 |
| True % .. .. .. | 7.0 | 7.0 | 7.0 | 7.0 |
| Error .. .. .. | +.0 | +0.6 | +0.6 | +1.2 |

The Maroon coloured pieces showed the largest error. This is 1.2% and is from the point of view of sampling of no significance. The total error over all defects is 2.4 which is also insignificant.

**Experiment 4.**

In this case a bag of 140 lbs. copra was treated so as to contain 4 lbs. 15½ ozs. or 3.5% of each colour. A sample of 50 ozs. was again used. The results are tabulated below :—

| Sample No. | Black. | Green. | Red. | Maroon. |
|---|---|---|---|---|
| 1 .. .. .. | 3.3 | 1.5 | 1.5 | 1.5 |
| 2 .. .. .. | 1.3 | 1.3 | 0.3 | 2.8 |
| 3 .. .. .. | 0.8 | 2.0 | 4.0 | 2.0 |
| 4 .. .. .. | 3.0 | 0.5 | 3.3 | 1.0 |
| 5 .. .. .. | 0.5 | 1.0 | 5.0 | 3.0 |
| 6 .. .. .. | 0.5 | 2.0 | 1.0 | 2.0 |
| 7 .. .. .. | 0.5 | 2.0 | 3.3 | 3.0 |
| 8 .. .. .. | 2.0 | 2.0 | 1.3 | 1.3 |
| 9 .. .. .. | 2.5 | 1.3 | 3.8 | 2.0 |
| 10 .. .. .. | 2.3 | 1.3 | 1.5 | 4.3 |
| 11 .. .. .. | 3.3 | 3.8 | 1.1 | 1.3 |
| 12 .. .. .. | 2.6 | 4.5 | 0.8 | 1.9 |
| 13 .. .. .. | 3.3 | 5.0 | 3.7 | 2.5 |
| 14 .. .. .. | 1.0 | 1.0 | 2.1 | 3.7 |
| 15 .. .. .. | 1.7 | 2.0 | 3.9 | 4.9 |
| 16 .. .. .. | 1.9 | 3.6 | 1.5 | 0.6 |
| 17 .. .. .. | 3.1 | 2.5 | 0.5 | 1.4 |
| 18 .. .. .. | 2.4 | 2.7 | 1.3 | 4.2 |
| 19 .. .. .. | 2.5 | 4.0 | 1.2 | 1.6 |
| 20 .. .. .. | 3.4 | 1.3 | 1.0 | 1.9 |
| Total .. .. | 41.9 | 45.3 | 42.1 | 46.9 |
| Average .. .. .. | 2.1 | 2.3 | 2.1 | 2.3 |
| Av. % .. .. .. | 4.2 | 4.6 | 4.2 | 4.6 |
| True % .. .. .. | 3.5 | 3.5 | 3.5 | 3.5 |
| Error .. .. .. | +0.7 | +1.1 | +0.7 | +1.1 |

Again the error is small enough to be allowable. A sample of 50 ozs. has proved its efficiency in copra containing 3.5, 7.0, 14.0 defects and also in 14.28 to 56% total defects. It may therefore be taken as a satisfactory weight.

## METHOD OF OBTAINING SAMPLES.

It has already been demonstrated that copra is very irregular in shape and size. This fact precludes the use of any such simple means of taking samples as the instrument used in cacao inspection. To pierce the bag and remove 50 ozs. of copra would cause serious damage. It would be, in addition, no simple task. The only method which can even be considered is the straightforward one of opening the bag at its mouth, pouring its contents on the ground and taking the sample by means of a wooden spade.

This has its disadvantages for it means that, in actual sampling, copra inspection will require a larger labour force than does cacao. It implies that a certain amount of interference with the consignment before shipping is inevitable. Against this, however, let it be remembered that the copra industry is a small one and the merchants are enthusiastic—an advantage of great importance.

Again, the analysis of copra is a different task from cacao analysis. Every sample of cacao has to be taken to the inspection office and cut up. Two labourers working on the beach can provide labour for six to eight men in the office. This problem is absent from copra inspection. The analysis of copra is simple ; the officer-in-charge will be able to carry out his examination at the same time as his labourers are removing and returning the samples. It would therefore seem possible that increase of expenditure on the beach may be balanced by a saving in the examination.

## ACTUAL PROCEDURE IN SAMPLING.

Further than stating the above facts this paper cannot go. Only by actual practice can the scheme be tested and then difficulties which crop up can be removed. Three facts alone would seem to be obtained :—

1. The sample should not weigh less than 50 ozs.

2. Percentage must be determined by weight.

3. The copra must be bulked.

These general principles should form a basis on which copra inspection can be formulated and afterwards, if necessary, the method can be modified in the light of greater experience.

PAPER No. XXVI.

# TRIALS OF CERTAIN METHODS OF SAMPLING PALM KERNELS.

By G. D. ROSS and J. L. SCOTT.

The phenomenal increase in the production of Gold Coast cacao has deprived the palm kernel industry of its wonted prosperity, and to-day it occupies a very minor place in the export list. That such an important product should be thus neglected is a matter which is giving the Government serious consideration and in the meantime steps are being taken to give it every possible stimulus. The first move in this must be an attempt to improve the quality of the kernels, a task which will be undertaken by the Produce Inspectorate of this Department and it is probable that some system of beach inspection analagous to the system employed for cacao will shortly be introduced.

## DEFECTS AFFECTING COMMERCIAL VALUE OF KERNELS.

There are three groups of defects which cause the value of palm kernels to depreciate. They are :—

1. Mouldy, soft and decomposed kernels.
2. Insect-attacked kernels.
3. Shell, fibre and extraneous matter.

The third defect is perhaps the most prevalent one and it introduces a difficulty which is not present in cacao sampling. The primitive method of removing the shell by hand is not efficient and the result is that a large proportion of the kernels have particles adhering to them. Some idea of the significance of this fact may be gained when it is known that buyers always assume that at least 5% of the weight of every bag is made up of shell. Those pieces form a very heterogeneous collection and they are of such irregularity of size and shape that no conception of their percentage can be obtained by mere count. For that reason a method of weighing must be adopted.

## METHOD OF OBTAINING SAMPLES.

The palm kernels themselves are fairly regular in shape. They are a little more bulky than cacao beans and the adhering shell prevents them from passing through the narrow slot on the cacao sampler. It was found, however, that this difficulty disappeared when the slot was made seven-tenths of an inch in width. The process of removing the sample is thus similar to that used in cacao sampling.

## SIZE OF SAMPLE.

A series of trials was carried out for the purpose of finding the smallest sample capable of giving an efficient result.

Palm kernels do not present a good medium for sampling experiments. When a sample has been removed from a bag the shell adhering to the kernels must be removed in order to have its percentage calculated. This means that when the sample is replaced in the bulk it has changed its form and is possibly a different substance as far as the sampler is concerned. The method was tried however and the change in form did not have any significant effect on the selective capacity of the sampler, as the experiments described in this paper will show.

### Experiment 1.

A bag of kernels of unknown quality and weighing 168 lbs. was used in this experiment. A sample weighing 200 grams, was taken in the usual way by means of the sampler. After this analysis it was not returned to the bulk because it was thought that the removal of the adhering pieces of shell might have changed the selective capacity of the kernels to the sampler. Twenty such samples were taken and the results are given in the table below.

| Sample No. | Shell, Fibre and Dirt. | Soft, Mouldy and Decayed. | Insect Attacked. |
|---|---|---|---|
| 1 .. .. .. | 8.0 | 1.3 | 13.1 |
| 2 .. .. .. | 10.3 | — | 7.5 |
| 3 .. .. .. | 15.0 | — | 3.8 |
| 4 .. .. .. | 16.1 | — | 13.3 |
| 5 .. .. .. | 11.5 | — | 16.0 |
| 6 .. .. .. | 9.8 | — | 30.9 |
| 7 .. .. .. | 22.3 | — | 20.1 |
| 8 .. .. .. | 13.5 | — | 5.8 |
| 9 .. .. .. | 10.9 | 2.9 | 16.4 |
| 10 .. .. .. | 14.2 | 3.3 | 15.1 |
| 11 .. .. .. | 13.6 | 5.9 | 16.2 |
| 12 .. .. .. | 17.4 | — | 10.9 |
| 13 .. .. .. | 10.5 | 3.6 | 18.8 |
| 14 .. .. .. | 16.1 | 6.7 | 15.2 |
| 15 .. .. .. | 10.4 | 1.4 | 14.4 |
| 16 .. .. .. | 13.7 | 1.5 | 4.7 |
| 17 .. .. .. | 11.1 | 2.5 | 6.5 |
| 18 .. .. .. | 14.6 | 7.3 | 8.0 |
| 19 .. .. .. | 12.9 | 4.3 | 8.2 |
| 20 .. .. .. | 13.8 | — | 15.8 |
| Total .. .. .. | 265.7 | 40.6 | 260.7 |
| Average .. .. | 13.3 | 2.0 | 13.0 |
| Percentage .. .. | 6.7 | 1.0 | 6.5 |

The contents of the bag were then taken and analysed completely. The actual composition of the whole was found to be as follows :—

| *Shell, Dirt and Fibre.* | *Mouldy, Soft and Decayed.* | *Insect attacked.* |
|---|---|---|
| 8.6% | 0.3% | 4.1% |

This means that the picture given by the average of twenty samples differed from the true result by—

| *Shell, Dirt and Fibre.* | *Mouldy, Soft and Decayed.* | *Weevilly.* |
|---|---|---|
| 1.9% | 0.7% | 2.4% |

These errors are not so large as to condemn a 200 gram sample. It only remained to try the sample out on kernels of different percentage defects.

**Experiment 2.**

Such inherent defects as mouldiness and insect larvæ can easily be represented by the process of painting the kernels in colours which represent them. Shell however presented a different problem. This was a question as to whether shell which adhered to the kernels was selected in the same way as loose shell by the sampler. If it was then the percentage of shell could be made up by adding shell to the bag in place of kernels. This experiment aimed at determining whether adhering shell differed from loose shell as a sampling item.

| Sample No. | Shell, Fibre. | Kernels. |
|---|---|---|
| 1 .. .. | .2% | 6.8 |
| 2 .. .. | .1 „ | 6.9 |
| 3 .. .. | .2 „ | 6.8 |
| 4 .. .. | .1 „ | 6.9 |
| 5 .. .. | .2 „ | 6.8 |
| 6 .. .. | .3 „ | 6.7 |
| 7 .. .. | .2 „ | 6.8 |
| 8 .. .. | .3 „ | 6.7 |
| 9 .. .. | .2 „ | 6.8 |
| 10 .. .. | .3 „ | 6.7 |
| 11 .. .. | .2 „ | 6.8 |
| 12 .. .. | .2 „ | 6.8 |
| 13 .. .. | .2 „ | 6.8 |
| 14 .. .. | .2 „ | 6.8 |
| 15 .. .. | .2 „ | 6.8 |
| 16 .. .. | .1 „ | 6.9 |
| 17 .. .. | .2 „ | 6.8 |
| 18 .. .. | .1 „ | 6.9 |
| 19 .. .. | .2 „ | 6.8 |
| 20 .. .. | .3 „ | 6.7 |
| Total .. .. .. .. .. | 4.0 „ | 136.0 |
| Average .. .. .. .. | 0.2 „ | 6.8 |
| Percentage .. .. .. .. | 2.9 | 97.1 |

Twenty samples were taken from a bag containing 168 lbs. of kernels of unknown quality. After each sample had been analysed it was not returned to the bulk. The results are tabulated below. This experiment was carried out at Aburi and a scale with avoirdupois weights was used, whereas the first experiment was carried out at Winneba where the metric system of weights was used. For that reason a seven ounce sample was used in this case, that being approximately equal to 200 gms.

It will be noted that the samples are very equal in their shell content and for that reason the average percentage may be taken as fairly accurate. This means that the bag contained approximately 4.9 lbs. of shell.

A weight of 4 lbs. 14 ozs. of shell was painted white and placed in the bulk of the same bag from which an equivalent weight of kernels and unpainted shell had been removed. The whole was thoroughly mixed and twenty 7 oz. samples removed in the usual way. This time however they were returned to bulk after analysis and examined.

The results are tabulated below :—

| Sample No. | Weight of Shell. | Weight of Kernels. |
|---|---|---|
| 1 .. .. .. | 0.1 | 6.9 |
| 2 .. .. .. | 0.2 | 6.8 |
| 3 .. .. .. | 0.1 | 6.9 |
| 4 .. .. .. | 0.2 | 6.8 |
| 5 .. .. .. | 0.3 | 6.7 |
| 6 .. .. .. | 0.2 | 6.8 |
| 7 .. .. .. | 0.3 | 6.7 |
| 8 .. .. .. | 0.2 | 6.8 |
| 9 .. .. .. | 0.1 | 6.9 |
| 10 .. .. .. | 0.1 | 6.9 |
| 11 .. .. .. | 0.2 | 6.8 |
| 12 .. .. .. | 0.1 | 6.9 |
| 13 .. .. .. | 0.1 | 6.9 |
| 14 .. .. .. | 0.1 | 6.9 |
| 15 .. .. .. | 0.3 | 6.7 |
| 16 .. .. .. | 0.3 | 6.7 |
| 17 .. .. .. | 0.2 | 6.8 |
| 18 .. .. .. | 0.2 | 6.8 |
| 19 .. .. .. | 0.3 | 6.7 |
| 20 .. .. .. | 0.2 | 6.8 |
| Total .. .. | 3.8 | 136.2 |
| Average .. .. .. | 0.19 | 6.8 |
| Percentage .. .. | 2.7 | 97.1 |

The difference between the result gained by sampling in which the pieces of shell adhere and those in which they are loose does not seem to affect the selective capacity of the sampler.

## Experiment 3.

The knowledge gained in Experiment 2 made it possible to make bags of kernels of known defects and thus in this experiment the accuracy of the seven ounce sample in bags containing different percentages of defects was tested. A bag containing 168 lbs. had 4.7% of its weight painted white, 4.7% painted blue and was made to contain 4.7% of shell. Twenty samples weighing 7 ozs. were taken and an analysis followed by a thoroughly remixing with the bulk was made in each case. The results are given below :—

| Sample No. | White. | Blue. | Shell. |
|---|---|---|---|
| 1 .. .. .. | 0.3 ozs. | 0.3 ozs. | 0.4 ozs. |
| 2 .. .. .. | 0.4 „ | 0.4 „ | 0.4 „ |
| 3 .. .. .. | 0.4 „ | 0.4 „ | 0.2 „ |
| 4 .. .. .. | 0.4 „ | 0.3 „ | 0.4 „ |
| 5 .. .. .. | 0.4 „ | 0.3 „ | 0.3 „ |
| 6 .. .. .. | 0.3 „ | 0.4 „ | 0.4 „ |
| 7 .. .. .. | 0.3 „ | 0.4 „ | 0.4 „ |
| 8 .. .. .. | 0.4 „ | 0.3 „ | 0.4 „ |
| 9 .. .. .. | 0.4 „ | 0.4 „ | 0.3 „ |
| 10 .. .. .. | 0.3 „ | 0.3 „ | 0.4 „ |
| 11 .. .. .. | 0.5 „ | 0.3 „ | 0.3 „ |
| 12 .. .. .. | 0.2 „ | 0.3 „ | 0.4 „ |
| 13 .. .. .. | 0.3 „ | 0.3 „ | 0.4 „ |
| 14 .. .. .. | 0.4 „ | 0.3 „ | 0.5 „ |
| 15 .. .. .. | 0.5 „ | 0.3 „ | 0.2 „ |
| 16 .. .. .. | 0.5 „ | 0.4 „ | 0.4 „ |
| 17 .. .. .. | 0.3 „ | 0.3 „ | 0.3 „ |
| 18 .. .. .. | 0.4 „ | 0.3 „ | 0.4 „ |
| 19 .. .. .. | 0.3 „ | 0.3 „ | 0.5 „ |
| 20 .. .. .. | 0.4 „ | 0.4 „ | 0.3 „ |
| Total .. .. .. | 7.4 „ | 6.7 „ | 7.3 „ |
| Average .. | .. 0.4 „ | 0.3 „ | 0.4 „ |
| Percentage .. .. | 5.7 | 4.3 | 5.7 |

The percentage of white, blue and shell given by taking 20 samples differs from the known true contents of the bag by 1.0%, 0.4% and 1.0% respectively. This is an accurate enough result for sampling purposes.

## Experiment 4.

Another bag of kernels was made to contain 14.2% white kernels, 14.2% blue kernels and 25.6% of shell. Twenty samples each weighing 7 ozs. were taken in the same way as in last Experiment. The results are tabulated on the following page.

| Sample No. | White. | Blue. | Shell. |
|---|---|---|---|
| 1 .. .. .. | 1.0 | 1.1 | 1.7 |
| 2 .. .. .. | 1.0 | 1.3 | 1.4 |
| 3 .. .. .. | 1.0 | 1.0 | 1.6 |
| 4 .. .. .. | 0.6 | 1.2 | 1.7 |
| 5 .. .. .. | 0.9 | 1.0 | 1.6 |
| 6 .. .. .. | 0.9 | 1.0 | 1.4 |
| 7 .. .. .. | 0.9 | 1.1 | 1.6 |
| 8 .. .. .. | 1.0 | 1.0 | 1.7 |
| 9 .. .. .. | 0.8 | 0.9 | 1.6 |
| 10 .. .. .. | 0.9 | 1.0 | 1.7 |
| 11 .. .. .. | 0.9 | 1.1 | 1.4 |
| 12 .. .. .. | 1.2 | 1.1 | 1.7 |
| 13 .. .. .. | 1.0 | 0.8 | 1.5 |
| 14 .. .. .. | 0.9 | 1.0 | 2.0 |
| 15 .. .. .. | 0.6 | 1.3 | 1.9 |
| 16 .. .. .. | 0.6 | 1.3 | 1.9 |
| 17 .. .. .. | 0.9 | 1.1 | 1.7 |
| 18 .. .. .. | 0.9 | 1.0 | 1.9 |
| 19 .. .. .. | 0.9 | 1.0 | 2.0 |
| 20 .. .. .. | 0.7 | 0.9 | 1.9 |
| Total .. .. | 17.6 | 21.2 | 32.9 |
| Average .. .. | 0.9 | 1.1 | 1.6 |
| Percentage .. .. | 12.9 | 15.7 | 22.9 |

The White, Blue and Shell given by the average differ from the true answer by 1.3%, 1.5% and 2.7%. Again, for all practical purposes the results are accurate.

## CONCLUSIONS.

It is now apparent that a seven ounce sample is large enough to give an indication of the quality of palm kernels. It has been demonstrated that the ordinary sampler, with the slight modification already mentioned, can remove the samples. Except for the determining of defects by weight, the sampling of palm kernels will be very similar to cacao sampling. The amount of time spent in analysing a sample will probably be similar. The inherent defects of kernels can be seen without cutting them. This saving in labour, however, will be balanced by the necessity of removing the adhering shell.

## PAPER No. XXVII.

# FOODSTUFFS IN THE DAGOMBA DISTRICT OF THE NORTHERN TERRITORIES.

By G. C. COULL.

The Dagomba is, on the whole, vegetarian in his diet. Animals are not slaughtered for meat as in a country where meat forms a part of the diet, but if wild animals or birds are killed they are eaten. Only at times of festivals is meat eaten.

Fish is eaten by that part of the population which lives in proximity to rivers.

Eggs are seldom eaten.

Food is made from the following plants :—

| Common Name. | Botanical Name. | Dagomba Name. |
|---|---|---|
| **Cereals.** | | |
| Guinea corn red .. .. | *Sorghum Vogelianum*, Staph. | Kaziegu |
| ,, ,, white .. | ,, ,, ,, | Kapielle |
| Millet .. .. .. | *Pennisetum typhoideum*, Rich. | Za |
| Maize .. .. .. | *Zea Mays*, Linn. | Kaluwana |
| Rice .. .. .. | *Oryza sativa*, Linn. .. .. | Sinkafa |
| Acha .. .. .. | *Digitaria exilis*, Staph. .. | Kabuga |
| Early Millet .. .. | *Pennisetum* sp. .. .. | Nara |
| **Roots.** | | |
| Yam .. .. .. | *Dioscorea sativa*, Linn. .. | Nyuya |
| Cassava .. .. .. | *Manihot utilissima*, Pohl. .. | Banchi. |
| Sweet potato .. .. | *Ipomoea Batatas*, Lam. .. | Wulejo |
| Fura-fura potato .. .. | *Coleus rotundifolius*, A. Chev. | Piaha |
| **Legumes.** | | |
| Cowpea .. .. .. | *Vigna Catjang*, Walp. .. | Tuya. |
| Swordbean .. .. | *Canavalia ensiformis*, D.C. .. | Kpaliegu |
| Groundnut .. .. | *Arachis hypogea*, Linn. .. | Sima |
| Bambarra groundnut .. | *Voandzeia subterranea*, Thouars. | Simpula |
| Geocarpa ,, .. | *Kerstingiella geocarpa*, Harms. | Simpie |
| Pigeon pea .. .. | *Cajanus indicus*, Sprang. .. | Adua |
| Dagarti bean .. .. | *Vigna* sp. .. .. .. | Senzie |
| **Leaves of :** | | |
| African locust bean tree .. | *Parkia filicoidea*, Welw. .. | Duo vise |
| Sesame .. .. .. | *Sesamum indicum*, Linn. .. | Zinzam |
| Kapok .. .. .. | *Eriodendron orientale*, Steud. | Gung vale |
| Baobab .. .. .. | *Adansonia digitata*, B. Juss. .. | Tukare |
| Tamarind .. .. .. | *Tamarindus indica*, Linn. .. | Puhu vale |
| Sweet potato .. .. | *Ipomoea Batatas*, Lam. .. | Wulejo vale |
| Okro .. .. .. | *Hibiscus esculentis*, Linn. .. | Man'vale |
| | *Ceratotheca sesamoides*, Endl. | Bungu |

| Common Name. | Botanical Name. | Dagomba Name. |
|---|---|---|
| **Flavourings.** | | |
| Pepper .. .. .. | *Capsicum frutescens*, Linn. .. | Nanzua |
| Onion .. .. .. | *Allium cepa*, Linn. .. .. | Gab'nyule |
| Okro .. .. .. | *Hibiscus esculentis*, Linn. .. | Mana |
| Locust beans .. .. | *Parikia filicoidea*, Welw. .. | Kpalagu |
| Kapok seed .. .. | *Eriodendron orientale*, Steud. | Kantong |
| **Fats.** | | |
| Shea butter .. .. | *Butyrospermum Parkii*, Kotschy | Tanga kpam |
| Groundnut oil .. .. | *Arachis hypogea*, Linn. .. | Sim'kpam. |
| Palm oil .. .. .. | *Elæis guineensis*, Jacq. .. | Kukpale kpam |
| STIMULANTS. .. | | |
| Kola .. .. .. | *Cola ocuminata*, Schott.. .. | Guli. |
| Tobacco .. .. .. | *Nicotiana Tabacum*, Linn .. | Nansara, taba. |
| Tiger nut .. .. .. | *Cyperus esculentis*, Linn .. | Nansaga. |

The same foodstuffs are used, practically throughout the Northern Territories. At the approach of the forest region yams are replaced by cassava, and guineacorn is replaced by maize.

Most foods are of the consistency of dough, and they are usually accompanied by a small calabash of soup. The method of eating is to take a little food on the fingers and dip it into the soup, which is usually highly flavoured with peppers.

Foods are prepared for eating at home, and also for selling in the markets, and, as a rule, the market foods are not eaten in private houses; market foods are made for travellers, and traders who do not belong to the country.

Dagomba names are used throughout, and the following is a list of the various foods classified under the various headings :—

## DESCRIPTION OF FOODS.

**Saǥam.**—The general term for all foods.

**Da'saǥam.**—(Market food). Anything prepared for selling.

**Sa'koro.**—(Root food). Sakorioko and banchi.

**Saǥ'tuliga.**—(Lit. hot food). This term is applied to any flour boiled to a thick paste and eaten with soup. The flour may be made from any cereal, or any dried tuber or root. Kasiegu (guinea corn), za (millet), kaluwana (maize), sinkafa (rice) kabuga (*Paspalum* sp.), nara (*Pennisetum*), jelong (dried yam), banchi (dried cassava), zim (a mixture of kaziegu, za, and jelong).

NOTE.—All the above foods are not masticated. They are simply put in the mouth and swallowed.

**Binubra.**—(Any food which is masticated). Nyuya, nungnyobieregu, piaha, wulejo, tua sinkafa, tubani, simpie and simpula.

Under this heading come the plants which are chewed. Guli (kola nut), and nansaga (tiger nut).

**Binyura.**—(Cereal food which is taken in liquid form). Fula, kafa, koko, pampam, kukogli, dam (Peto) the native beer is also included here.

**Binchimna.**—(Any food fried in shea butter whether animal or vegetable). Asiakomo, chiabala, waina, masa, dundunkolo, nimni, and zahan.

**Ziere.**—(The general name for all soups). Tukarkuka, manineri, bungu, zinzam, nansutogo, and sima.

## MANUFACTURE OF FOODS.

(a) **Sakorioko.** Yam boiled for an hour and a half and then beaten in a mortar to make fou-fou.

(b) **Banchi.**—Same but made from cassava.

(c) **Sag'tuliga.**—The grain, or dried root or tuber, is ground to a flour. It is then boiled with water till it forms a thick paste and is eaten thus.

(d) **Binubra;**

**Nyuya.**—Yam simply cut into slices and then boiled.

**Nungnyobieregu.**—Same as nyuya but eaten with salt and shea butter.

**Piaha.**—Boiled Fura-fura potatoes.

**Wulejo.**—Boiled sweet potatoes.

**Tua sinkafa.**—Hulled rice is boiled, squeezed into small balls, and eaten with soup.

**Tubani.**—Made from common beans and bambarra ground beans. The beans are beaten in a mortar and the testa removed. They are then ground to a meal, cold water added, and stirred to form a thick paste. Then made into balls boiled, and so eaten.

**Simpie.**—Made from geocarpa ground beans. Beans beaten in a mortar and the testa removed. Boiled in water, salt and shea butter added and eaten so.

**Simpula.**—Same as simpie, but made from bambarra ground bean.

(e) **Binyura ;**

**Fula.**—Made from millet, sometimes from rice and guinea corn. The grain is ground to a meal, mixed with water, made into balls, and boiled for about an hour in water. Next the balls are beaten in a mortar until like fou-fou and again made into small balls. A ball is mixed with water to the consistency of gruel and then drunk.

**Kafa.**—Made from guinea corn, millet and maize. The seed is pounded in a mortar, and then steeped in water for one day. It is again put into a mortar and beaten wet. It is boiled for about five hours, ground between stones, and sieved. To the thin paste which has passed through the sieve about twice its bulk of water is added, the whole well stirred, and left till next morning when the flour has settled. The water is next decanted from the sediment into another pot, twice its bulk of fresh water added, and put on a fire to boil. Enough water is added to the sediment to form a thin paste and this is then added slowly to the other pot as soon as it boils, being well stirred all the time. It is boiled about two hours until it forms a gruel and may be drunk so. It may also be left until it cools, when it sets. It is then made into balls added to water and drunk as a thirst quenching drink.

**Koko.**—Made from millet, guinea corn and maize. Same as kafa but seed only steeped about two hours instead of a day. The paste is added to the boiling water all at the same time and the whole boiled for five minutes only, and then drunk as a gruel.

**Pampam.**—(Same as koko but pyea added). Made from guinea corn, millet and maize. Seeds steeped in water then put in a heap and covered with leaves and left one to three days till they germinate. Next dried in the sun and when thoroughly dry, ground to a meal. (This is called pyea). In the evening about one-eighth of the meal is boiled for an hour with just enough water to cover it ; after this the remaining seven-eighths is mixed with it and well stirred, sufficient water being added from time to time to keep the whole mass of the consistency of a very thick paste. Water is now added just to cover this paste, and the whole left till the next morning. Next morning a pot with water about twice the bulk of the paste is put on the fire and boiled. Some of the boiling water is added slowly to the paste and well stirred until it is thin enough to pour out of the pot. When of such a consistency, it is poured quickly into the boiling water, well stirred and kept boiling for ten minutes. It is now poured into another pot and is drunk like gruel. It makes a sweet drink.

**Kukogli.**—Made from guinea corn and millet. Grain ground to a flour and flavoured with peppers and ginger; about a handful of peppers or three to four handfuls of ginger to 14 lbs. of flour. After the evening meal if there is any sag'tuliga left over it is mixed with the flavoured flour into a thick dough covered with water, and left till next morning. Then same process as pampam. Drunk hot.

**Dam** (peto).—The native beer. Made from guinea corn or maize. The grain is steeped in water for two days and then dried in the sun for two hours. Next it is put in a heap and covered with leaves until the seeds begin to germinate, which usually takes place in from two to three days. It is now put in a hut until the germination has gone far enough, and then it is thoroughly dried in the sun. (This is called pyea). The whole mass is now ground into a rough meal. Two-thirds of the meal is put into a pot and boiled about six hours. When taken from the fire, the remaining third is thoroughly mixed with it and the whole mass left till the next morning. The sediment is thrown away and the liquid again boiled about six hours. It is then put into another pot and allowed to cool. The fruit of a small pumpkin plant (name unknown) *Lugga* sp. and some of the sediment from the last brewing is now added to the cold liquid. After standing a day the beer is ready for drinking. Some of the sediment is collected and kept for the next brewing.

(f) **Binchimna.**

**Asiakomo.**—Made from red and white commonly cultivated beans. The seed coat is removed by pounding. in a mortar, and then the beans are soaked in water for about four hours. Any remaining seed coats are now removed and the beans are beaten when wet into a rough kind of meal, and then mixed with water to the consistency of a thick porridge. They are next made into balls and boiled for about ten minutes in shea butter and then are ready for eating.

**Chiabala.**—Made from millet and guinea corn. Same as asiakomo but the seeds ground to a fine flour and small balls boiled for about fifteen minutes in shea butter.

**Waina.**—Made from beans and bambarra ground bean. Same as asiakomo but seeds ground to a fine flour.

**Masa.**—Made from millet and guinea corn, and occasionally maize. Grain pounded in a mortar to a meal.

Two-thirds of the meal is made into porridge and boiled for about half an hour. The other one-third is now added and the whole thoroughly stirred, sufficient cold water being added from time to time to keep the porridge of the same thickness. It is now left to cool. Made into small cakes and boiled in shea butter for ten minutes, and is then ready for eating.

**Dundunkolo.**—Yam cut in slices and fried in shea butter.

**Nimni.**—Any kind of flesh fried in shea butter: cattle, sheep, goats, or birds.

**Zaham.**—Any kind of fish fried in shea butter.

(g) **Ziere.**—The essential for all soups is Kpalagu (dawa-dawa), made from the seeds of *Parkia filicoidea*, the African locust-bean tree. Practically no soup is made without this as one of the ingredients and if this is not available then Kantan is used.

**Kpalagu.**—Made from the seeds of *Parkia filicoidea* The seeds are boiled for twenty-four hours to soften the seed-coat. Next the seeds are trodden to break the seed coats. The whole mass is now put into water, calabash by calabash, and the seed coats, which float, are skimmed off. The seeds are now boiled in water and the resulting mass which forms a thick paste is put into a calabash, covered with leaves and left for three days, by which time it smells very badly to Europeans. It is then ready for use as a flavouring for soup.

**Kanton.**—The same as kpalagu but made from the seeds of kapok and baobab.

**Tukar-kuka.**—Made from the leaves of baobab. Leaves dried in the sun, pounded in a mortar, sieved, then added to the soup.

**Mani.**—Made from Okro. The fruit is boiled in water beaten in a mortar, and then added to the soup.

**Botcha.**—(Ash water) is made as follows:—A calabash pierced with many small holes is filled with ash, any kind of wood ash is used, except that from the tree pulumpung (*Sterculia tomentosa* Guill et Perr), which is said to cause a person to swell up, and one and a half times the bulk of water is added and drained off. This ash water is often used for making soups with, instead of using plain water.

**Neri.**—The seeds are shelled, roasted, then ground between stones to a paste. This paste is added to the soup to be flavoured.

**Bungu.**—Prepared as in the case of neri above.

**Zinzam.**—Prepared as above.

**Nansutogo.**—Made from peppers. Large red peppers are dried ground and sieved. Then added to the soup.

**Sima.**—Made from groundnuts and prepared as in the case of neri.

The following are home foods : –Sag'tuliga, nungnyobieregu, piaha, simpie, simpula, kukogli, nimni, zaham, and all soups.

The following are the market foods :—Sakorioko, banchi nyuya, welejo, tua, sinkafa, tubani, fula, kafa, koko, pampam, asiakomo, chiabala, waina, masa and dundunkolo.

Dam, the native beer is consumed at home, and sold in the market.

## METHODS OF USING THE LAND.

There are several rotations practised by the Dagombas, which vary according to the fertility of the ground, or the amount of land available.

Generally the ground is poor, and the farmer has to depend on letting the ground lie fallow for several years in order to enrich it.

There is no actual scarcity of land except round the large towns, and it sometimes happens that a man's farm is as far away as three miles from his house. The farm is not all in one place, but is divided up into a series of plots ; one plot will be near the house, and will probably be manured with house refuse, or sheep, cattle or horse manure. In this farm he grows tobacco, peppers, guinea corn or maize and it is not very large (about ½ acre).

Another plot will perhaps be near a swamp, and there he will grow rice, fura-fura potatoes, tobacco, or maize.

The largest plot will be in the bush, and here the main crops of yams and cereals are grown, the farmer spending a day in any plot which needs attention.

The rotations practised are as follows :—

### (a) Extensive.

**Rotation I.**—1st year. Yams with beans, okro, cotton, pumpkin, neri, or fura-fura potato interplanted, sometimes all together, sometimes perhaps only one of these crops in addition to yams.

2nd year. Maize and guinea corn with groundnuts, bambarra-beans, cowpeas or neri (*Citrullus vulgaris*) interplanted. Then the ground lies fallow for four to six years.

**Rotation II.**—1st year. Millet.

2nd year. Maize and guinea corn with groundnuts or neri. Then lies fallow for four to six years.

**Rotation III.**—1st year. Bungu (*Ceratotheca sesamoides*).

2nd year. Millet or guinea corn and maize with groundnuts or neri interplanted.

**(b) Intensive.**

**Rotation I.**—1st year. Yams, millet or rice and okroes.

2nd year. Maize, guinea corn, or millet, either singly or in combination, and groundnuts or bambarra-beans or neri interplanted.

3rd year. Yams, etc., again and so on.

**Rotation II.**—1st year. Maize and millet.

2nd year. Guinea corn and millet.

Millet and swamp rice are grown year after year on the same piece of ground; the former usually near a compound and the latter on swampy ground.

Fura-fura potatoes are more commonly grown by themselves, on a wettish piece of land but not in a swamp, and a new piece of ground taken next year.

Tobacco is usually grown near a man's compound and if it is planted in a farm a piece of ground is chosen near a good supply of water, but not on land liable to flooding. Around Zuaragu and Navrongo a second crop of tobacco is planted in April.

Peppers are grown usually under the shade of *Parkia filicoidea* or *Tamarindus indica*. A few bushes under a tree are harvested for three to four years then another tree is chosen, and a few plants put in there.

In addition to the crops mentioned in the above rotations the following are also grown as follows :—

Sweet potato on ridges near the house.
Cowpea with guinea corn.
Geocarpa with maize and millet.
Dagarti bean with maize.
Pigeon pea as a hedge round a farm.

One farmer therefore has usually an example of every rotation each year, so that he gets all the various crops he requires for food.

## CULTIVATION OF CROPS.

When the ground is cleared to make a farm several methods are employed depending on what is or has been grown on the plot.

If the ground is virgin bush, the grass and all the undergrowth is burned, and the ash then worked into the soil in the making of heaps or ridges. If yams are to be planted all small stems of shrubs are left standing to make supports for the yams.

On old farmed land if the previous crops were cereal, the stalks are cut down and worked into the land with the hoe, during the process of making heaps or ridges.

During the growth of a crop the land is weeded as necessary and ridges and heaps are pared away, but not too much.

Practically the only two cultural operations are making heaps and making ridges, and crops are grown on heaps, on ridges, on the sides of heaps and ridges, or between heaps and ridges.

Heaps are usually about 4 ft. apart, and 3 ft. to 4 ft. diameter conical and from $2\frac{1}{2}$ ft. to 3 ft. high. They are made merely by heaping up the top 5 ins. of soil, the man standing with his back to the heap, working round in a circle, and throwing the soil up with a hoe between his legs.

Ridges are usually about $3\frac{1}{2}$ ft. to 47 ft. apart, about 2 ft. wide, and flat topped, the furrow being up to 10 ins. wide and about 5 ins. below the original surface of the ground, making it 10 ins. deep They are made with the native hoe by turning two 10 ins. sods side by side face downwards upon one side of an intervening space about 27 ft. wide, which is the base of the ridge. By doing the same again, on the other half of the intervening space, the ridge is made. Occasionally another stroke of the hoe is employed to deepen the furrow, and this earth is used to cap the ridge. These ridges are not made too long, and are traversed by cross ridges at frequent intervals, depending upon and conforming with the ground surface; this prevents water from a heavy storm washing away the soil, and so conserve the moisture.

When there is only a small growth of weeds covering the ground the bases of heaps and ridges are never cultivated; the earth is merely turned face downwards on the base. This saves greatly in labour and, by the time the crop is planted, the vegetation, turned over and buried, has rotted, and becomes available to the plant.

Ridges are made, following a crop grown on heaps, merely by splitting the line of heaps, and following a crop grown on ridges, by splitting the ridges.

The subsequent cultivation consists in weeding with a hoe, as occasion demands, the heaps and ridges being scraped down, and in some cases the ridges are earthed up again after this operation.

There are few crops grown by themselves; the usual rule is for several crops to be grown simultaneously on the same land but the different crops are planted, ripen, and are harvested at different times.

The following shews the various combinations of crops grown simultaneously. By simultaneously is meant during the same season, though it often happens that one crop is harvested when the next crop is just appearing; and it is sometimes difficult to realize that two or more crops have been taken from the same piece of ground that season.

## TIMES OF PLANTING AND HARVESTING NATIVE FOODCROPS IN DAGOMBA DISTRICT.

| Crop. | Planted. | Harvested. | Crops which may be planted with those shewn in column 1. |
|---|---|---|---|
| Guinea corn early | May (end) .. | November .. | Maize. |
| ,, late .. | do. .. | Dec. to Jan. .. | Groundnuts, neri, bambarra beans. |
| Maize .. .. | May (beginning) .. | Aug. to Sept. .. | Guinea corn. |
| Rice .. .. | June (end), July | November .. | Yams or maize. |
| Early millet, Nara | April .. .. | June .. .. | By itself. |
| Millet late .. | May (end) .. | Dec. to Jan. .. | Guinea corn, yams, groundnut, bambarra, neri. |
| Yam .. .. | Jan. to April .. | Nov., Jan., and February. .. | Beans, okro, pumpkin, neri, fura-fura potatoes. |
| Cassava .. .. | May .. .. | Dec. to Jan. .. | Yams. |
| Sweet potato .. | June from cuttings | Nov. to Dec. .. | By itself. |
| Fura-fura potato .. | June .. .. | do. .. | By itself, yams. |
| Cowpea .. .. | May .. .. | November .. | Guinea corn. |
| Bambarra-bean .. | June (end) .. | do. .. | Yams, cereals or by itself. |
| Geocarpa .. .. | do. .. | Oct. to Nov. .. | do. |
| Pigeon pea .. | do. .. | Dec. to Feb. .. | As hedge. |
| Dagarti bean .. | May .. .. | Sept. to Oct. .. | Cereals. |
| Neri .. .. | June (middle) .. | Oct. to Nov. .. | Cereals, principally yams. |
| Bungu .. .. | July to August .. | March .. .. | By itself. |
| Sesame .. .. | July .. .. | February .. | do. |
| Okro, dry season .. | May .. .. | September .. | Yams. |
| ,, wet ,, .. | April .. .. | June to Aug. .. | do. |
| Pepper .. .. | May .. .. | Nov. to Dec. .. | Under leguminous trees. |
| Groundnut .. | May (end) .. | Aug., Sept., or November. .. | With cereals. |
| Tobacco .. .. | August .. .. | Dec. to Jan. .. | By itself. |

Yams are planted in heaps and with them, depending on conditions, may be beans, okroes, pumpkin, neri or fura-fura potatoes, late-millet or rice.

Maize, guinea corn and millet are frequently grown together and groundnuts, bambara-beans, cowpea, or neri interplanted; sometimes all are planted together, or one or more cereals, with one or more of the other crops.

Rice is frequently grown with yams or maize. The yams are the earliest ones to be lifted, and the rice is planted between the heaps just before the yams are harvested, which are clear of the ground before the rains appear, and it gives the appearance of rice planted on a previous year's yam farm. Similarly the maize is harvested just as the rice is planted in the furrows of the ridges. During the rains this ground becomes flooded, and will remain so for from one to two months.

## METHODS OF PLANTING AND HARVESTING CROPS.

All fit members of the family take part in doing some portion of the work of one or other of the above operations of planting and harvesting. The men usually plant the main crops and tobacco, and the women the okroes, peppers, pumpkins, and neri.

### Planting.

Yams are planted in the heaps, small yams being used as sets, about 6″ from the top on the North side, so that they are on the shady side of the heap during the dry weather. A hole is scooped out with the hand and the yam inserted.

Fura-fura potatoes are planted by themselves on the heaps similar in size to the yam heap, but flat topped, and not conical. Occasionally they are planted at the bottom of the sides of yam heaps along with yams.

All cereals and leguminous seeds are planted on ridges, and two men are usually engaged in the operation. One man goes along and makes small holes, along both sides, on the flat topped ridges, with a stick about 4′ 6″ long. Another man with the seeds in a calabash comes behind and drops the required number of seeds into a hole and covers them over by brushing in some soil with his big toe. By this method, bending the back is completely avoided.

Peppers, okroes, and pumpkins, planted by the women, are usually done completely by hand. A small hole is made with the finger, the seed put in, and covered over by hand.

Neri, bungu and sesame are planted in the same way as cereals, and are planted by women.

Tobacco is sown in a nursery, and the seedlings transplanted when about 4″ to 6″ high.

Millet is very often grown from suckers from the previous year's crops. These suckers are cut off and the stem and leaves cut down to about 6″ and then transplanted.

**Harvesting.**

Yams are harvested by men, women and children as occasion demands. They are merely tunnelled out from the heap.

Fura-fura potatoes are dug up with a hoe.

Maize cobs are harvested by women and children.

Guinea corn, millet, and rice are harvested by men and women. The heads are cut off, and the stems left standing.

Peppers, okroes, pumpkins and neri are harvested as required, by women.

Groundnuts are harvested by the whole family. There are two methods of doing this :—

**Method I.**—If the groundnuts are harvested immediately they are ripe. A man goes along with a hoe, and loosens the earth in which the nuts are embedded—a skilful job to avoid breaking the flower stalks. He then grips the root system of the plant, and pulls it out bringing with it the nuts. Collectors gather the plants, and usually carry them to a clean space under a tree, where the nuts are removed by hand.

**Method II.**—If the crop has been left in the ground. By the dry season all stalks have dried up, and a man goes along with a piece of flat stick, or a piece of broken calabash and stirs up the soil. The nuts are then collected into baskets by others following. This is a long and tedious business, but sometimes unavoidable if a man has large amounts of produce growing. This is the only crop which can remain in the ground any length of time without taking harm, and, consequently, if the farmer has other crops to harvest, he leaves the groundnuts till the last.

Bungu and sesame are harvested by men and women. The plants are merely pulled up.

Tobacco leaves are gathered and the tobacco made by men.

## METHODS OF THRESHING AND STORING.

1. Maize is threshed by hand-picking, but is usually stored in the cob.

2. Millet is threshed with a flail on a beaten piece of ground, and winnowed by the wind. It is stored after threshing.

3. Guinea corn is threshed with a flail. It is carried from the field in bundles of heads, and stored till required when it is threshed.

4. Rice is threshed in the field by being well dried and then shaken till the seed falls out when it is collected and stored.

5. Bungu and sesame are left in the sun till the pods are completely dry. It is then shaken by hand on a beaten piece of ground, till the seeds all fall out, then they are collected, and stored.

6. **Neri.**—The seed of this gourd is obtained by the following method :—The gourds are collected together and the hard skin cracked. They are then put into a heap, and left to ferment for about a week. After this the seeds are washed and stored.

7. Groundnuts are stored in the shell.

8. Leguminous plants (with the exception of groundnuts), are put in the sun til the pods are thoroughly dried, threshed with a flail, and stored.

9. Okro and peppers are picked as required during the rains. For dry season needs the fruits are collected, dried thoroughly and stored.

10. Millet, rice, bungu, sesame, all leguminous plants, neri, are threshed in the field.

11. Guinea corn and cowpeas are threshed at home.

## PAPER No. XXVIII.

# TEST AT KUMASI INVESTIGATIONAL STATION OF A PRESCRIBED SEQUENCE OF FOOD-CROPS 1923–1928.

(*The trials described were laid down and conducted by T. Hunter, and the paper prepared by G. G. Auchinleck*).

In the Gold Coast, food-farms are usually established on newly cleared forest-land and the area is abandoned after only a few crops have been grown. The custom is characteristic of countries where the supply of land is greatly in excess of the needs or energies of the population. It results in a dearth of records concerning the effect of long-continued cropping on the productivity of the land.

In view of the absence of farm records and the improbability of obtaining them, the Department of Agriculture has found it necessary to lay down certain farming-trials so that a volume of experience may be accumulated. The principal purpose of the trials is to provide an answer to the statement, which is common locally, that the land will not bear long-continued cropping with annual food-crops.

There are other equally valuable uses of such trials. They serve as observation-centres and give rise to questions which later form the bases of rigid experimental work. Long-continued cropping is especially fertile in problems of chemical or physical nature concerning the soil, of incidence of pests and diseases, of physiological interrelations between plants, and of bacterial phenomena in the soil. In addition, the records of yields are especially valuable in a country where reliable information on the point is not obtainable from farmers.

The value of this type of trial, therefore, is precisely the same as that of a farm on which book-keeping is precisely and regularly done. It suggests innumerable problems but only rarely can solve them. The present trials should be criticised with this in mind, and it will be found that there is room in a tropical Department of Agriculture for a type of trial which may become the centre of local farming-lore.

## DESCRIPTION OF THE TRIALS.

The field on which the trials under consideration are being carried on is 2.5 acres in area and is divided into ten sections of equal size and similar shape. Five of the sections are devoted to repeated cropping with an annual food-plant, while on the other

five the same five plants follow each other on each section in a prescribed order. The five plants include two root-crops (cassava and yams), a cereal (maize), a malvaceous fruit (okro), and a legume (groundnut). The lay-out of the field and the order of planting of the crops are shewn in the following plan :—

| Section A. | Section B. | Section C. | Section D. | Section E. |
|---|---|---|---|---|
| 1923 Cassava | 1923 Maize | 1923 Okro | 1923 Yam | 1923 Ground-nut. |
| 1924 Maize | 1924 Okro | 1924 Yam | 1924 Ground-nut | 1924 Cassava |
| 1925 Okro | 1925 Yam | 1925 Ground-nut | 1925 Cassava | 1925 Maize |
| 1926 Yam | 1926 Ground-nut | 1926 Cassava | 1926 Maize | 1926 Okro |
| 1927 Groundnut | 1927 Cassava | 1927 Maize | 1927 Okro | 1927 Yam* |
| 1928 Cassava | 1928 Maize | 1928 Okro | 1928 Yam | 1928 Ground-nut |
| 1923 } 1924 } 1925 } 1926 } Cassava. 1927 } 1928 } | 1923 } 1924 } 1925 } 1926 } Maize. 1927 } 1928 } | 1923 } 1924 } 1925 } 1926 } Okro. 1927 } 1928 } | 1923 } 1924 } 1925 } 1926 } Yam* 1927 } 1928 } | 1923 } 1924 } 1925 } 1926 } Ground-nut 1927 } 1928 } |
| Section F. | Section G. | Section H. | Section I. | Section J. |

Sections A to E are planted with a five-year rotation and one cycle of the rotation is complete and in addition the first member has recurred. Sections F to J were clearly intended as controls, and the results from these will be dealt with first.

## INDICATIONS OF DIMINUTION IN YIELD.

The yields obtained from Sections F to J are given in the following table :—

*Yields recorded in pounds per acre.*

| Year. | Section F Cassava. | Section G Maize. | Section H Okro. | Section I Yam. | Section J Groundnut. |
|---|---|---|---|---|---|
| 1923 .. | 13,824 | 586 | Failed | 6,808 | 742 |
| 1924 .. | 7,196 | 236 | Failed | 540 | 256 |
| 1925 .. | 8,056 | 836 | 438 | 1,844 | 460 |
| 1926 .. | 7,616 | 144 | 168 | Failed | 236 |
| 1927 .. | 5,152 | 368 | 762 | — | 468 |
| 1928 .. | 6,584 | 298 | 778 | 2,632 | 200 |

(*Replaced by Sweet potatoes in 1927).

The yam and okro yields are incomplete and will be omitted from further consideration. The yields of the other three crops are irregular, presumably owing to climatic fluctuations, but on the whole they tend to fall, as may be seen from the following table of calculated means :—

| Period of Years. | Cassava. | | Maize. | | Groundnut. | |
|---|---|---|---|---|---|---|
| | Mean Yield. | % of 1st Period. | Mean Yield. | % of 1st Period. | Mean Yield. | % of 1st Period. |
| 1923–5 .. | 9,692 | — | 553 | — | 486 | — |
| 1924–6 .. | 7,622 | 78.6 | 406 | 73.4 | 317 | 65.2 |
| 1925–7 .. | 6,941 | 71.6 | 449 | 81.2 | 388 | 89.9 |
| 1926–8 .. | 6,450 | 66.5 | 270 | 48.8 | 301 | 61.9 |

The yields do diminish after the first year, and the diminutions appear to increase with repeated croppings. It is unlikely that climatic conditions gradually worsened during the period of trial, and it is reasonable to assume that productivity of the land is progressively lessening. It will not be possible to decide this point until the time-duration of the trials has been long enough to smooth away the effects of climatic variations.

## TESTING THE EFFECT OF ROTATION.

The series A to E is intended, like the other series, for the measurement of any alteration in productivity of the field caused by cropping. It differs from the other series, however, in that four other kinds of crops are inserted between any two recurrences of the same crop on the same section.

The assumption underlying the whole trial is that the productivity of the field in both series will be altered as a result of annual cropping, but that either the degree or else the nature of the alteration will not be the same in the two series.

In trying to obtain evidence on this point, it is necessary to compare yields from plots in series F to J with those of plots in series A to E. The following table gives the yields for the first and sixth years of each crop in the two series.

| Year. | Yields recorded in pounds per acre. | |
|---|---|---|
| | Rotation planting (Series A to E). | One-crop planting (Series F to J). |
| 1923 Cassava | 12,888 | 13,824 |
| 1928 .. .. .. | 9,156 (=71.0%) | 6,584 (=46.9%) |
| 1923 Maize | 484 | 586 |
| 1928 .. .. .. | 340 (=70.2%) | 298 (=50.9%) |
| 1923 Groundnuts | 696 | 742 |
| 1928 .. .. .. | 396 (=56.9%) | 200 (=26.9%) |

Two points are observable about these results. Firstly, in all cases the yields for 1928 are lower than those for 1923. Secondly, the 1928 yields are nearer to those for 1923 in series A to E (71.0%, 70.2%, 56.9%) than in the case of series F to J (46.9%, 50.9%, 26.9%).

It is unsafe to accept these results as sure proof that productivity of the field lessens more slowly when the rotation is used than when the same crop is repeated annually. Each yield-record is the result of one determination only. To secure more convincing evidence, the trials will have to be repeated through several more cycles in order that climatic variations may be smoothed away.

The facts that the 1928 figures are all lower, that the lessening of yield is greater in all cases in series F to J, and that the yields in series F to J appear to diminish progressively afford some ground, however, for suspecting that productivity lessens in both series and lessens more rapidly in series F to J.

## FURTHER TESTS OF EFFECT OF ROTATION.

In the last section of this paper, opposite pairs of sections were considered (A with F, B with G and E with J). It is now proposed to compare the results from the control plots (F, G and J) with those from the rotation-plots (A to E) for each year.

The procedure is very seriously open to question, since very few records occur from which an opinion can be formed of the degree of uniformity of the field. These records are limited to the 1923 yields (*see* last table), and from them only five single comparisons are possible (A with F, B with G, etc., etc.); the difference between the two comparates in each case is not excessive, but this may have been due to climatic accident.

The results are tabulated below:—

| Year of planting. | Same Crop repeated (Series F–J). | Other Crops (Series A–E). |
|---|---|---|
| | (Cassava yields). | |
| 1923 (No crop preceding) | 13,824 | 12,888 |
| 1924 ( 1 ,, ,, ) | 7,196 | 8,932 |
| 1925 ( 2 ,, ,, ) | 8,056 | 10,380 |
| 1926 ( 3 ,, ,, ) | 7,616 | 17,472 |
| 1927 ( 4 ,, ,, ) | 5,152 | 6,804 |
| 1928 ( 5 ,, ,, ) | 6,584 | 9,156 |
| | (Maize yields). | |
| 1923 (No crop preceding) | 586 | 484 |
| 1924 ( 1 ,, ,, ) | 238 | 76 |
| 1925 ( 2 ,, ,, ) | 836 | 512 |
| 1926 ( 3 ,, ,, ) | 144 | 376 |
| 1927 ( 4 ,, ,, ) | 368 | 472 |
| 1928 ( 5 ,, ,, ) | 298 | 340 |

| Year of Planting. | Same Crop repeated (Series F–J). | Other Crops (Series F–J). |
|---|---|---|
| | (Groundnut yields). | |
| 1923 (No crop preceding) | 742 | 696 |
| 1924 ( 1 „ „ ) | 256 | 272 |
| 1925 ( 2 „ „ ) | 460 | 588 |
| 1926 ( 3 „ „ ) | 236 | 276 |
| 1927 ( 4 „ „ ) | 468 | 304 |
| 1928 ( 5 „ „ ) | 200 | 396 |

The three observable points about these results are that the first year's figures are in all cases but three the highest, that yields in both series are irregular, and that in most cases the figures for the rotation series (A to E) are higher than those for the one-crop series (F to J). As each test is in single, however, it is unsafe to draw any conclusions, and repetition of the whole cycle many times is necessary.

## EFFECT OF ALTERING PRECEDING CROP.

It will be useful at this point to state the general facts that are known about rotation of crops. If the same crop be repeated annually on a field, the productivity of the field progressively declines with respect to that crop. The rate of decline can be retarded by planting other crops between any two recurrences of the crop under consideration. The amount of this retardation depends upon the crops which are inserted, and both the rate of decline and the amount of retardation differ for different soils.

There is evidence that a rotation does not act always merely as a period of rest, but that in certain cases a definite stimulus or a set-back to productivity results. In other words one crop may have a definitely beneficial or a harmful effect on a succeeding crop. Clearly, a very complex set of relations is set into operation by planting a series of different crops successively on the same land, since the duration of the harmful or beneficial effect of each is rarely known. In addition, the effect of a first crop on a second may alter the ordinary effect of the second on a third and so on.

In the case of tropical crops, practically nothing is known of the inter-relations of one with another The results of the trials under consideration are grouped in the following table with a view to observing whether any such relations are apparent.

| Crops which precede those under consideration (in order of date) | Yields in pounds per acre. | | | |
|---|---|---|---|---|
| | Year. | Cassava. | Maize. | Groundnut. |
| None .. .. .. .. .. | 1923 | 12.880 | 484 | 696 |
| Cassava .. .. .. .. .. | 1924 | — | 76 | — |
| Yam .. .. .. .. .. | ,, | — | — | 272 |
| Groundnut .. .. .. .. | ,, | 8,932 | — | — |
| Okro, Yam .. .. .. .. | 1925 | — | — | 588 |
| Yam, Groundnut .. .. .. | ,, | 10,380 | — | — |
| Groundnut, Cassava .. .. .. | ,, | — | 512 | — |
| Maize, Okro, Yam .. .. .. | 1926 | — | — | 276 |
| Okro, Yam, Groundnut .. .. | ,, | 17,472 | — | — |
| Yam, Groundnut, Cassava .. .. | ,, | — | 376 | — |
| Cassava, Maize, Okro, Yam .. .. | 1927 | — | — | 304 |
| Maize, Okro, Yam, Groundnut .. | ,, | 6,804 | — | — |
| Okro, Yam, Groundnut, Cassava .. | ,, | — | 472 | — |
| Cassava, Maize, Okro, Yam, Groundnut | 1928 | 9,156 | — | — |
| Maize, Okro, Yam, Groundnut, Cassava | ,, | — | 340 | — |
| Groundnut, Cassava, Maize, Okro, Yam | ,, | — | — | 396 |

The first observable point is that, in spite of the elaborate lay-out of the trials, no determination occurs more than once in any one year. The cycle will have to be repeated many times before any conclusions can be drawn.

The simplest comparison would be to place results of first planting of a crop alongside of the results of its planting after each of the other two. Unfortunately, there are no records for groundnuts following maize or cassava, or for maize following yam or groundnut, or for cassava following yam or maize as may be seen from the plan of the trials. Similar blanks occur in the cases of third, fourth, fifth and sixth year plantings.

## CONCLUSIONS.

Conclusions drawn from these results may be summed up as follows :—

(1) These trials shew that cassava, maize and groundnut can be grown for six years in succession on the trial-field.

(2) There are indications that the productivity of the field lessens progressively when one crop is grown for six years in succession.

(3) There are some indications that productivity lessens at a slower rate when other crops are grown between two recurrences of the same crop.

(4) No valid conclusions can be drawn concerning the effect of one crop on another.

It is clear that problems of inter-relations between crops will have to be attacked by means of special one-purpose trials.

## PAPER No. XXIX.

# A UNIFORMITY TRIAL WITH MAIZE.

By W. H. BECKETT and S. R. B. FLETCHER.

An area of eighty-three 1/40 acre square plots at Asuansi Experiment Station was under Maize in 1928. The area had been cleared in 1926 and no crop grown in 1927. Cutlassing and shallow digging were done prior to sowing the seed on 22nd and 23rd March, 1928.

Four seeds were sown per hole about two inches deep. The holes were 3 feet by 3 feet, giving 121 stands per 1/40 acre plot. Germination data were collected on 3rd and 4th April, by counting vacant stands in each plot and substracting from 121. As even a plant as possible was required and therefore all vacancies were supplied at that time.

Counts of the number of stalks were made on 23rd May, but owing to some lodging, and the difficulty of making accurate counts in the leafy stands, reliance is not attached to these figures.

Harvesting was done on 16th and 17th August. Each plot was harvested separately and counts made of the number of ears. Owing to shortage of supervision, it was impossible at the time to obtain weights of the ears, and of corn for each plot, without sacrificing reliability. Fifteen plots were therefore chosen *At Random* by Mr. Fletcher, and accurate weights of the ears and grain taken for those plots.

Table I gives the data as collected. Plate No. LIA shows the plot in plan. Those plots for which weights were taken are bounded by a thick line.

| Plot No. | Germination Count. | No. of Ears. | Weight of Ears. | Weight of Grain. | No. of Stalks 23/5/28. |
|---|---|---|---|---|---|
| | | | lbs. | lbs. | |
| 1 .. | 96 | 270 | 84 | 56 | 360 |
| 2 .. | 102 | 284 | — | — | 309 |
| 3 .. | 99 | 280 | — | — | 394 |
| 4 .. | 95 | 263 | — | — | 384 |
| 5 .. | 94 | 252 | — | — | 365 |
| 6 .. | 110 | 265 | — | — | 416 |

TABLE I—*contd.*

| Plot No. | Germination Count. | No. of Ears. | Weight of Ears. | Weight of Grain. | No. of Stalks 23/5/28. |
|---|---|---|---|---|---|
| | | | lbs. | lbs. | |
| 7 .. | 112 | 205 | — | — | 428 |
| 8 .. | 107 | 266 | — | — | 387 |
| 9 .. | 117 | 183 | — | — | 505 |
| 10 .. | 115 | 110 | — | — | 453 |
| 11 .. | 109 | 180 | — | — | 445 |
| 12 .. | 118 | 194 | — | — | 415 |
| 13 .. | 119 | 180 | — | — | 436 |
| 14 .. | 121 | 210 | — | — | 412 |
| 15 .. | 103 | 212 | 88 | 58 | 412 |
| 16 .. | 119 | 282 | — | — | 417 |
| 17 .. | 118 | 245 | — | — | 416 |
| 18 .. | 117 | 253 | 92 | 63 | 397 |
| 19 .. | 119 | 208 | 83 | 52 | 415 |
| 20 .. | 114 | 105 | — | — | 414 |
| 21 .. | 121 | 117 | — | — | 409 |
| 22 .. | 116 | 122 | — | — | 404 |
| 23 .. | 120 | 114 | — | — | 418 |
| 24 .. | 121 | 120 | 38 | 23 | 406 |
| 25 .. | 121 | 105 | — | — | 412 |
| 26 .. | 117 | 135 | — | — | 418 |
| 27 .. | 113 | 205 | 77 | 50 | 352 |
| 28 .. | 103 | 220 | — | — | 365 |
| 29 .. | 114 | 265 | — | — | 381 |
| 30 .. | 119 | 212 | — | — | 415 |
| 31 .. | 118 | 305 | 99 | 66 | 450 |
| 32 .. | 118 | 230 | — | — | 414 |
| 33 .. | 120 | 197 | — | — | 406 |
| 34 .. | 120 | 200 | — | — | 411 |
| 35 .. | 119 | 190 | — | — | 415 |
| 36 .. | 119 | 200 | — | — | 410 |
| 37 .. | 111 | 150 | — | — | 403 |
| 38 .. | 91 | 122 | — | — | 454 |
| 39 .. | 120 | 213 | — | — | 410 |
| 40 .. | 120 | 170 | — | — | 437 |
| 41 .. | 115 | 190 | — | — | 409 |
| 42 .. | 120 | 190 | — | — | 401 |
| 43 .. | 108 | 243 | — | — | 433 |
| 44 .. | 119 | 244 | — | — | 389 |
| 45 .. | 121 | 230 | — | — | 386 |
| 46 .. | 120 | 234 | — | — | 373 |
| 47 .. | 106 | 205 | 79 | 59 | 412 |
| 48 .. | 115 | 255 | — | — | 407 |
| 49 .. | 119 | 184 | — | — | 413 |
| 50 .. | 121 | 197 | — | — | 421 |
| 51 .. | 121 | 155 | — | — | 433 |
| 52 .. | 121 | 130 | — | — | 377 |
| 53 .. | 118 | 207 | 53 | 31 | 408 |
| 54 .. | 118 | 162 | — | — | 413 |
| 55 .. | 121 | 110 | — | — | 427 |
| 56 .. | 113 | 80 | — | — | 413 |
| 57 .. | 116 | 157 | — | — | 375 |

TABLE 1—*contd.*

| Plot No. | Germination Count. | No. of Ears. | Weight of Ears. | Weight of Grain. | No. of Stalks 23/5/28. |
|---|---|---|---|---|---|
| | | | lbs. | lbs. | |
| 58 .. | 116 | 130 | — | — | 381 |
| 59 .. | 120 | 140 | 51 | 29 | 350 |
| 60 .. | 118 | 130 | — | — | 422 |
| 61 .. | 119 | 153 | — | — | 416 |
| 62 .. | 120 | 150 | — | — | 444 |
| 63 .. | 116 | 180 | — | — | 393 |
| 64 .. | 84 | 137 | 37 | 20 | 206 |
| 65 .. | 105 | 160 | — | — | 375 |
| 66 .. | 92 | 140 | — | — | 395 |
| 67 .. | 102 | 155 | 71 | 41 | 411 |
| 68 .. | 103 | 140 | — | — | 352 |
| 69 .. | 110 | 174 | — | — | 394 |
| 70 .. | 108 | 154 | — | — | 400 |
| 71 .. | 117 | 160 | — | — | 371 |
| 72 .. | 105 | 176 | 62 | 42 | 404 |
| 73 .. | 119 | 120 | — | — | 377 |
| 74 .. | 106 | 168 | — | — | 412 |
| 75 .. | 109 | 115 | — | — | 410 |
| 76 .. | 75 | 123 | — | — | 409 |
| 77 .. | 96 | 116 | — | — | 359 |
| 78 .. | 81 | 135 | 50 | 33 | 258 |
| 79 .. | 121 | 137 | — | — | 405 |
| 80 .. | 110 | 121 | 45 | 30 | 339 |
| 81 .. | 112 | 73 | — | — | 385 |
| 82 .. | 121 | 91 | — | — | 393 |
| 83 .. | 119 | 95 | — | — | 380 |
| Sum .. .. | .. 9,321 | 14,785 | — | — | 33,091 |
| Mean .. .. | .. 112.3 | 178.1 | — | | 398.7 |

The standard deviation of the ear counts for all plots was calculated.

The mean number of ears .. =178.13

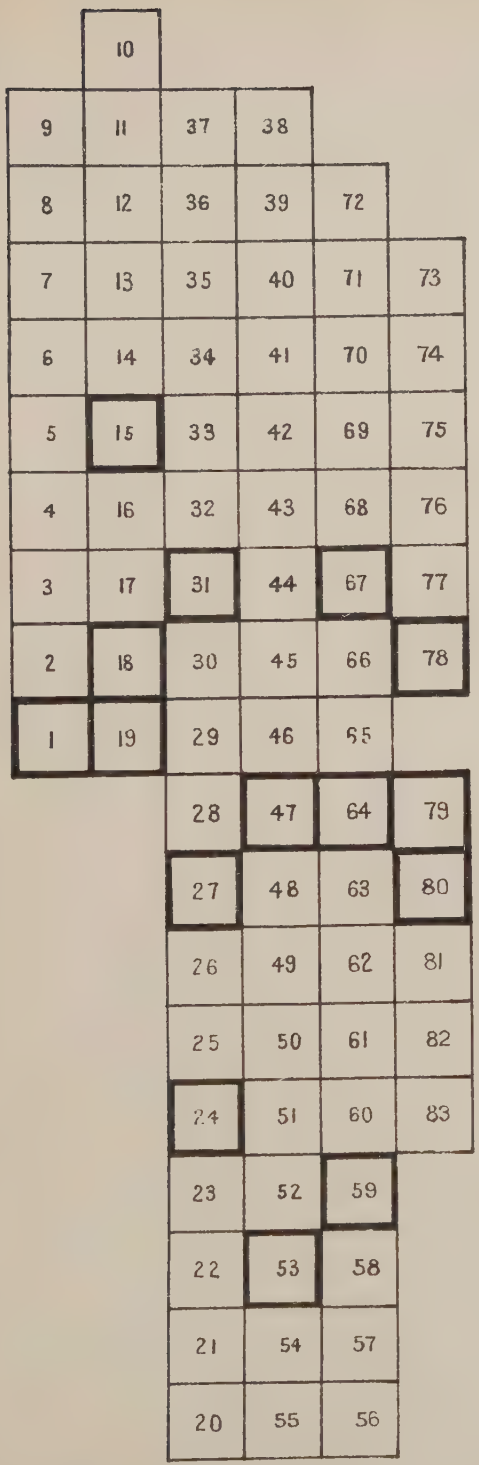
The S.E. for one plot .. .. = 55.5

The S.E. of the mean of 83 plots $= \frac{55.5}{\sqrt{83}} = 6.1$

These figures give an indication of the heterogeneity of the soil. The probable error for one plot is .67 x 55.5. For the mean of eight plots the probable error is therefore $\frac{.67 \times 55.5}{\sqrt{8}} = 13.1$

In a replicated experiment, using $\frac{1}{40}$ acre plots on this land, differences in the means of treatments each being replicated eight times, of 13.1, would be expected by pure chance, and only differences, due to treatment, larger than this could be measured by using eight replications. By using more replications smaller differences could be measured.

# MAIZE —— PLAN OF PLOTS.




Plots surrounded by heavy line were used for weight of ear and weight of grain data.

Mean no. of ears per acre (83 plots of $\frac{1}{40}$ acre) = 4492 lbs

Mean weight of ears per acre (15 plots of $\frac{1}{40}$ acre) = 2691 lbs

Mean weight of grain per acre (15 plots of $\frac{1}{40}$ acre) = 1741 lbs.

*Survey H.Q. Accra*

# TABLE II.

| Plot No. | Field Data. | | | Derived Data. | | Statistics calculated.—Difference | | | | Tables. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of ears. | Weight of ears. lbs. | Weight of grain. lbs. | Mean wt. of grain per ear. lbs. | Grain wt. Ear wt. % | Number of ears. | Weight of ears. | Weight of grain. | Mean wt. of grain per ear. | Grain wt. Ear wt. % |
| | A. | B. | C. | D. | E. | a. | b. | c. | d. | e. |
| 31 .. .. .. | 305 | 99 | 66 | .282 | 67 | 115 | 32 | 23 | .048 | 3 |
| 1 .. .. .. | 270 | 84 | 56 | .236 | 67 | 80 | 17 | 13 | .002 | 3 |
| 18 .. .. .. | 253 | 92 | 63 | .249 | 68 | 63 | 25 | 20 | .015 | 4 |
| 15 .. .. .. | 212 | 88 | 58 | .274 | 66 | 22 | 21 | 15 | .040 | 2 |
| 19 .. .. .. | 208 | 83 | 52 | .250 | 63 | 18 | 16 | 9 | .016 | — 1 |
| 53 .. .. .. | 207 | 53 | 31 | .149 | 59 | 17 | —14 | —12 | —.085 | — 5 |
| 47 .. .. .. | 205 | 79 | 59 | .288 | 75 | 15 | 12 | 16 | .054 | 11 |
| 27 .. .. .. | 205 | 77 | 50 | .244 | 65 | 15 | 10 | 7 | .010 | 1 |
| 72 .. .. .. | 176 | 62 | 42 | .239 | 68 | —14 | — 5 | — 1 | .005 | 1 |
| 67 .. .. .. | 155 | 71 | 41 | .264 | 58 | —35 | 4 | — 2 | .030 | — 6 |
| 59 .. .. .. | 140 | 51 | 29 | .207 | 57 | —50 | —16 | —14 | —.027 | — 7 |
| 64 .. .. .. | 137 | 37 | 20 | .146 | 54 | —53 | —30 | —23 | —.088 | —10 |
| 78 .. .. .. | 135 | 50 | 33 | .244 | 66 | —55 | —17 | —10 | .010 | 2 |
| 80 .. .. .. | 121 | 45 | 30 | .248 | 67 | —69 | —22 | —13 | .014 | 3 |
| 24 .. .. .. | 120 | 38 | 23 | .193 | 61 | —70 | —29 | —20 | —.041 | — 3 |
| Sums .. .. .. | 2,849 | 1,009 | 653 | 3.513 | 961 | | | | | |
| Means .. .. .. | 190 | 67 | 43 | .234 | 64 | | | | | |
| Standard Error .. .. .. | | | 15.2 | | | | | | | |
| Standard Error of Mean .. .. .. | | | 3.9 | | | | | | | |

The data of the fifteen plots mentioned above were analysed. These are arranged in descending order of number of ears in Table II, column A. Columns B and C give the relevant data for weights of ears and grain respectively. This arrangement enables correlation graphs to be made. Columns D and E are calculated from the data in A, B, and C. The sums and means of all columns were made and the differences in each series of data for the fifteen plots are entered in columns (*a*) to (*e*). The differences shown under columns (*a*) to (*e*) are measured from the means of columns A to E respectively.

Plates LXIIIA and LXIIIB show, in graphical form, the correlations of these differences.

It is seen from Figure II that there is only a general tendency for the weight of ears and of grain to be correlated with the number of ears. It is clear, therefore, that counts of number of ears are quite inadequate as yield figures for measuring the effect of a treatment in field experiment with maize. The correlation between the weight of ears and weight of grain is marked, but not close enough to render weight of ears data sufficiently reliable as an estimate of the weight of grain. In any experiment, the weight of grain is the primary yield figure required, and cannot be estimated accurately from counts or weights of ears.

A finer test was made by making a correlation graph of the percentage by weight of grain to ear, and the mean weight of grain per ear. This is given in Figure III.

Here there is no apparent correlation between these quantities and the number of ears. Fewer ears in a plot are not compensated by a higher weight per ear or a higher percentage of grain per ear, as might be expected. This compensating factor in spacing and tillering in cereals has been noticed by (*) Engledow at Cambridge and by (†) Maskell and Eden at Rothamsted. It is not apparent in this maize plot, although the supplying mentioned on page 222 may have some effect. As already noted, the number of stalks counts in Table I are not considered sufficiently reliable to use for making a statistical test of this point.

There is, however, a general tendency for the percentage of grain per ear and the mean weight of grain per ear to be correlated. Thus the actual weight of grain depends increasingly on the high percentage of grain per ear. It would be expected therefore that a treatment giving increased yields would have this effect, and in any trials, a sampling method making use of this grain ear weight ratio would be useful. Trials of sampling methods with maize to test these points are to be laid down at Asuansi for 1929 harvest.

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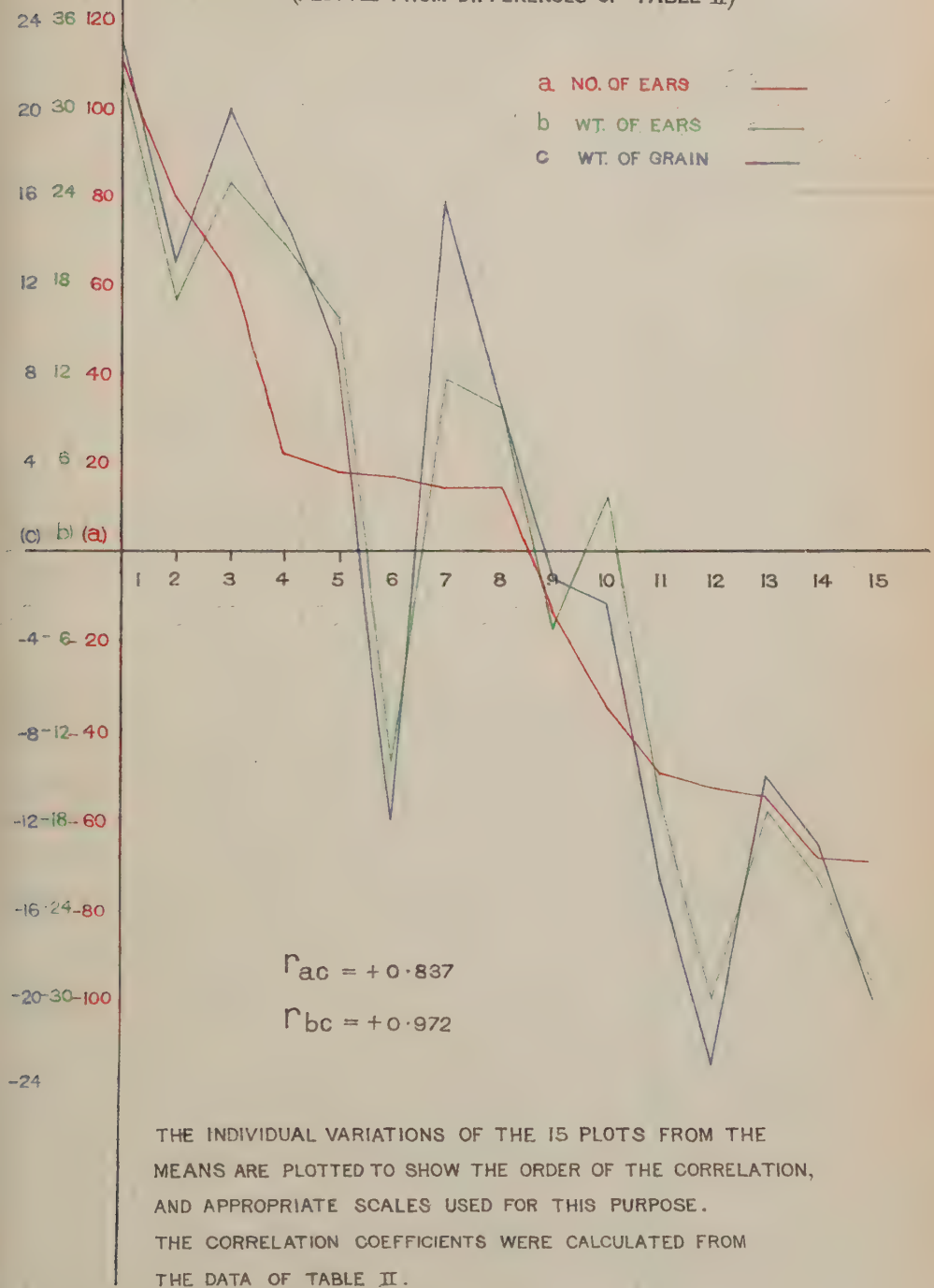
* L. R. Doughty and F. L. Engledow. Investigations on yield in the Cereals V. J. of Agric. Science XVIII, II.

† Eden and Maskel. The influence of Soil Heterogeneity on the Growth and Yield of Successive Crops. J. of Agric. Science, XVIII, II.

# MAIZE.

## CORRELATION GRAPHS.

(PLOTTED FROM DIFFERENCES OF TABLE II)

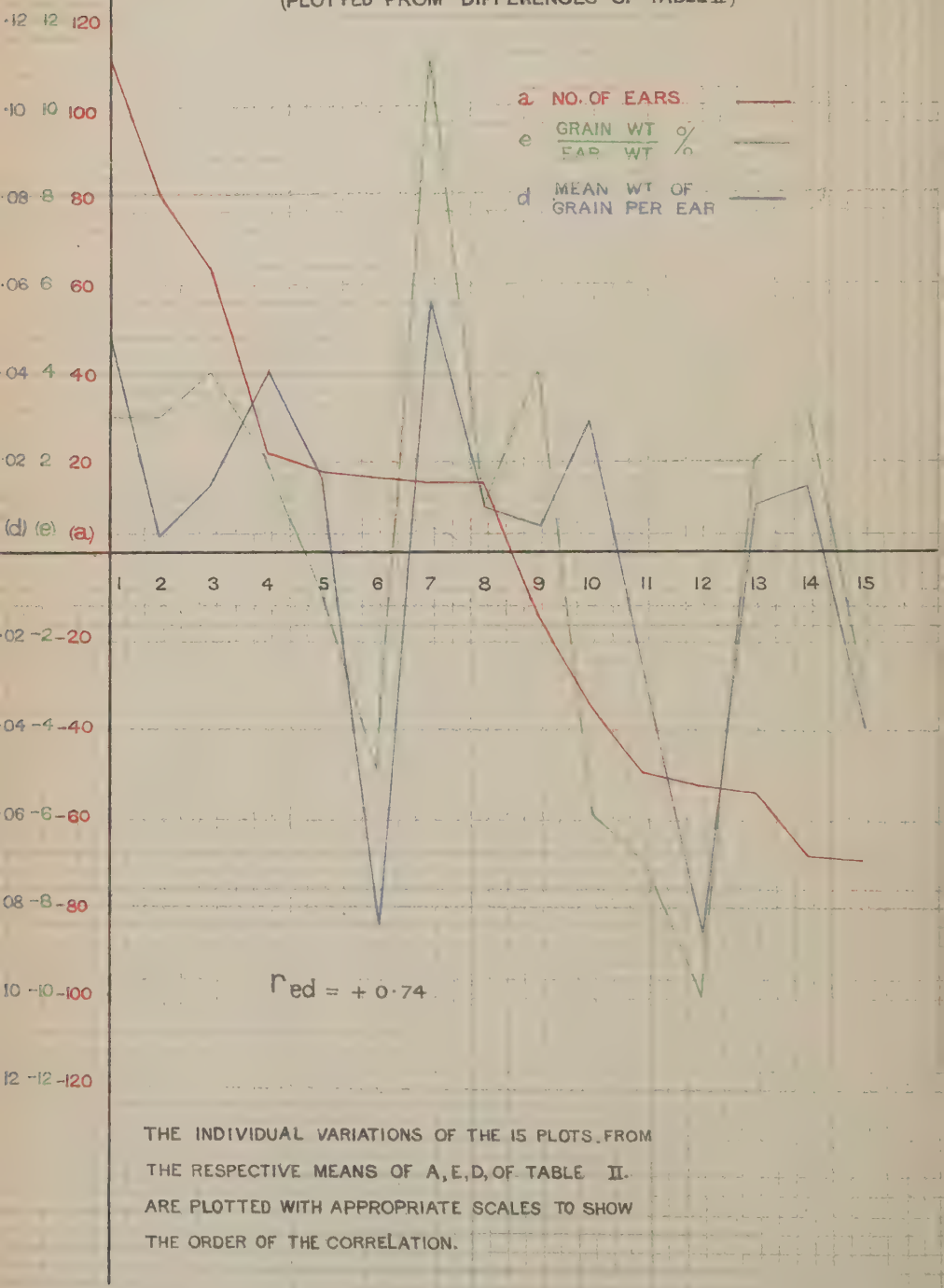



THE INDIVIDUAL VARIATIONS OF THE 15 PLOTS FROM THE MEANS ARE PLOTTED TO SHOW THE ORDER OF THE CORRELATION, AND APPROPRIATE SCALES USED FOR THIS PURPOSE. THE CORRELATION COEFFICIENTS WERE CALCULATED FROM THE DATA OF TABLE II.

# MAIZE.

## CORRELATION GRAPHS.

(PLOTTED FROM DIFFERENCES OF TABLE II)




THE INDIVIDUAL VARIATIONS OF THE 15 PLOTS FROM THE RESPECTIVE MEANS OF A, E, D, OF TABLE II. ARE PLOTTED WITH APPROPRIATE SCALES TO SHOW THE ORDER OF THE CORRELATION.

*Survey H.Q. Accra, 1929.*

## PAPER No. XXX.

# RESULTS OF A TRIAL SHIPMENT OF SHEA NUTS.

By J. E. Symond.

For many years the possibility of an export trade in Shea Kernels from the Northern Territories has been the subject of much comment, and very varied statements have been made as to the prospects. That there is a great quantity of this product scattered throughout the country there is no doubt, but whether this could ever be marketed profitably is debatable. To obtain reliable figures, the Department of Agriculture in 1928 collected a consignment of just over 15 tons and forwarded it for sale to England. The district of Western Dagomba, which is tapped by the main trunk road, was chosen.

## DETAILS OF THE TRIAL.

Freight to and charges in England were :—

**Ocean freight and marketing.**

| | | |
|---|---|---|
| Ocean freight at 45/- plus 10% per ton primage | 2.46 | |
| Master porterage .. .. .. .. .. | 0.18 | |
| Quay rent .. .. .. .. .. .. | 0.01 | |
| Watching .. .. .. .. .. .. | 0.03 | |
| Dues at 2/- less 5% .. .. .. .. | 0.09 | |
| Customs entry .. .. .. .. .. | 0.01 | |
| Cartage to store, housing, and delivery .. | 0.33 | |
| Rent (29th October to 17th November) at 4d. per week .. .. .. .. .. | 0.05 | |
| Agency and attendance .. .. .. .. | 0.06 | |
| Insurance .. .. .. .. .. .. | 0.02 | |
| Superintending .. .. .. .. .. | 0.03 | |
| Extra sampling .. .. .. .. .. | 0.03 | |
| Sample bags and carriage .. .. .. | 0.02 | |
| Brokerage at 1% .. .. .. .. | 0.14 | 3.46 |

Total cost £25.60 per ton.

The consignment realized £14 per ton. It is therefore obvious that there is no present prospect of a profitable industry in the shipment of kernels, as transport charges in the Gold Coast alone total £12.92 or nearly the value of the product. Some useful and interesting information has been gained however, in the collection of the consignment. In the discussion below the word "nut" means the kernel in its clean shell with no green pulp adhering.

**Collection of the Kernels.**

Briefly the preparation of the kernel consists of boiling the nuts to kill the germ, shelling and sun drying the kernels. The natives often give the kernels a further washing to improve the appearance. Of the 15 tons approximately half were bought ready prepared from villagers at a price of 1/3d. per kerosene tin full; which varies little from a weight of 28 lbs. With small presents to the chiefs, this cost worked out at £5 10s. per ton. Kernels well prepared and of good quality are sold in the open markets round Tamale for approximately the same price, and it is probable that the response would be quite fair if there was ever a steady demand for unlimited quantities.

**Cost of preparation.**

The remaining half of the consignment was obtained by purchase of nuts at 1/- per tin, preparation of the kernels being carried out by hired labour. It was found that nuts after preparation yielded only half their weight of kernels. Preparation costs were as follows:—On an average rate of pay of 7½d.; some women being employed.

| | *Per ton kernels.* £ | s. | d. |
|---|---|---|---|
| Boiling .. .. .. .. .. .. .. | 0 | 1 | 0½ |
| Shelling .. .. .. .. .. .. .. | 1 | 3 | 4 |
| Baskets and Twine .. .. .. .. .. | 0 | 0 | 6 |
| Collection of water and firewood, and drying of kernels | 0 | 7 | 6½ |
| | £1 | 12 | 5 |

The total cost for this half of the consignment was £9 8s. 11d. per ton. Too high a price was obviously paid for the nuts, but the heavy loss in weight after preparation was not anticipated.

A comparison of the cost of buying ready prepared kernels and of buying nuts and then preparing them is interesting. For large scale preparation it would be impossible to obtain sufficient labour at 7½d. and the current rate of 9d. would have to be paid. This would increase preparation costs to £1 18s. 11d. per ton and in comparison with buying prepared kernels, leave only £3 11s. 1d. per ton for collection. This means £3 11s. 1d. for two tons of nuts, or 5¼d. per kerosene tin full. Natives would be unlikely to sell at this price when they can get 1/3d. for the same tin full of kernels. It is also extremely doubtful whether hired labour would collect at this rate for the following reasons:—

1. Shea trees are thinly distributed round villages owing to the establishment of farms. Collection could not take place from the trees on which the people rely for their normal consumption, and labourers would therefore have to walk a minimum distance of 2–3 miles before collection which would increase daily as areas were exhausted.

2. Range of collection is limited to within reasonable distances of motor roads, as preparation must take place there. Transport costs are so high that additional charges for headloading kernels to the roads are out of the question.

3. It is difficult to gather large quantities of clean nuts without green pulp adhering to the shell; and additional work to remove this would be necessary. Also more supervision is needed than for simple purchase.

It would therefore appear that purchase of prepared kernels would be the more suitable system on which to concentrate.

## FACTORS AFFECTING PRODUCTION.

A limiting factor affecting production is undoubtedly population. Except in the extreme north population is nowhere dense, and large numbers are attracted south where higher wages can be obtained. Around centres of thick population trees are inevitably thinned out for making of farms, and the trees mature so slowly that growing the crop on plantation lines is not likely to appeal to the native grower.

A further limiting factor lies in the fact that the season for collection of nuts coincides with the commencement of the rains and the main farming season, which naturally absorbs the bulk of available labour. This is probably the reason why it has become the custom to regard all work on Shea as women's work. This custom would probably break down in the face of a strong demand for kernels, but is at present a real obstacle to collection of large quantities. The nuts cannot be left on the ground till after the farming season, as the grass grows too high and dense for them to be gathered then.

## PRICES PREVIOUSLY PAID.

It is interesting to note at this stage prices paid some years ago for kernels. In the Bulletin of the Imperial Institute Vol. X No. 2, July 1912, it is stated that the price in Northern Nigeria at Baro was £7 10s. per ton, and at Nupe 75 miles away from £4—£6 per ton.

## PROSPECTS FOR SHEA FAT.

From the above it would appear that the cheapest rate in Tamale for kernels is £7.3 per ton, i.e., £5.5 for purchase and £1.8 for transport to Tamale. Assuming that modern machinery allows of the extraction of 50% fat from the kernels this means an expenditure on kernels of £14.6 per ton fat. For export to England there would be a further transport charge of £13.22, and the product would therefore have to stand a charge of approximately £28 per ton plus all manufacturing charges. The price in England

of the fat is uncertain ; probably in the neighbourhood of £38 per ton. There is also an increasing internal trade in the product between the north and the forest areas. High prices are ruling as the demand is good, 6d. per lb. or £56 per ton being a common price. The situation warrants further investigation and the Department is instituting trials for the local expression of the fat.

## SUMMARY.

1. There is no prospect of Shea Kernels being exported profitably owing to high transport charges.
2. There are several limiting factors which preclude the collection of any really large quantity of the product.
3. There are possibilities in the local extraction of fat by proper machinery which warrant further investigation. This work is being undertaken.

PAPER No. XXXI.

# THE LOCAL EDIBLE-SNAIL INDUSTRY.

By J. S. MARTINSON.

## DISTRIBUTION.

Snails live in most parts of the Gold Coast where the forest is dense and damp. Although a few may be found here and there throughout the whole Colony, the collecting industry is confined to the wetter parts of the forest area.

The Trade snails as we will call them are unlike those to be found in other parts of the Colony and are of several varieties, viz.: Ottopey, Ottabira (or Opobiri) Nwatuntum (or Nwabiri) Nwakawkaw, Nwafufu, Nkochima, Nwahene, Nwahemma (or Atonkwah).

## VARIETIES OF TRADE SNAILS.

**Ottopey :** This variety is the largest in size and is not at all common although it is widely distributed all through the forest area. The shell is thin and somewhat brittle, light brown in colour with a series of longitudinal bold black stripes extending almost the whole length.

**Ottabira or Opobiri :** This variety is of two types, viz. :— Ottabiratuntum and Ottabirafufu (or Ottabirahene). Both have very thick shells. The shell of the former is of a light slaty colour, while the latter is of a pale greyish shade. In both cases the interior of the shell is highly glazed and of a light purple colour, while the flesh is black and coarse and on this account they are not much liked. This variety is not very common and is distributed over much the same area as the former.

**Nwatuntum :** This variety is one of the commonest of the trade snails. It is not as large as either of the former but is found in much greater numbers. The shell is thin and the colour a soft yellow decorated with deep black longitudinal stripes.

**Nwakawkaw :** This also is one of the more common trade snails and is found in abundance in all the forest areas. There are two distinct types of this variety. The shell is a pale yellowish brown in colour in both cases, but the distinctive longitudinal black decorations are more widely spread in the first type and less deep than in the case of Nwatuntum. In the second type the black decorations differ in that the colouring is chevroned within the lines.

Owing to the distinct yellow colour of Nwakawkaw it is easily seen by collectors and an easy victim of its natural enemies. Both are of the same size as Nwatuntum, and about the size of an ordinary common mango fruit.

**Nwafufu :** This variety is like the former and has two distinct types. Both possess very pale greyish shells which are thin and brittle. The flesh is white and of good flavour and is popular on that account.

The first type is distinguished by the faintly marked and narrow longitudinal stripes on the shell, whereas the second type is without any decorative markings on the shell.

**Nwahene :** This variety is almost as large as Ottopey and lives for a longer period than any other of the trade snails. The shell is of a pure dull white colour and is devoid of decoration.

This variety is very rare and in every Division native Bye-laws prohibit its collection. There is an age old superstition to the effect that the removal of this variety means the extinction of the trade snail of the district. So strong is the superstition that the people respect it, and will not intentionally destroy one of these snails.

**Atonkwah (or Queen Snail) :** As the name implies, this variety is of considerable importance and is of historical interest. Queen-like it is by no means common and there would appear to be nothing ordinary about this Queen, for it is generally admitted that no man has ever seen the King, or Consort, of this elusive snail. Collectors search eagerly for the Atonkwa knowing well that she will be accompanied by hordes of subjects to swell their catch. Although very limited in numbers the variety is widely distributed throughout the forest areas. To find one is a sure indication of good fortune, for collectors know that it indicates the presence in that locality of large quantities of the common varieties.

The shell of the Atonkwah is of a pale yellowish cream colour, decorated with faintly black longitudinal stripes. The latter are so faint in some cases that they are not apparent until the specimen is held up to the light. The shell is extremely thin like the finest china and very brittle. In size it compares favourably with the ordinary varieties.

**Nkonchima :** This variety is similar to Nwatuntum but, it differs in shade of the shell. The shell is deeply curled from the apex to fully half the entire length. The colour is similar to the Nwatuntum. It is not found in large quantities and always travels in company with the Nwatuntum.

# Plate LIV.

R. H. B. del.

John Bale Sons & Danielsson, Ltd

1 & 2, Ottabira. 3, Ottopey.
4, Atonkwa. 5, Nwakawkaw (var.)

## COLLECTING PERIOD.

The snails show themselves during two periods of the year, viz.: From about the middle of February to the end of April and from early September to the end of October. Those collected early in the year are known as the Sun Snails, and the late arrivals are known as the Regular Snails.

When retiring at the end of the feeding season each snail protects itself by sealing the entrance of the shell with a whitish transparent wax-like substance, the operculum, and remains in that state till the beginning of the next season.

## PREPARATION FOR MARKET.

The snails are collected in baskets, brought into the camp while still alive, and heaped together. Children are detailed to guard the heaps and see that none escape.

The shells are broken by a sharp knock on a large stone and adhering particles are removed from the body. The latter is then pulled sharply through the fingers to squeeze out the food, after which the body is thrown into a pan for washing. Only one washing is given and this with fresh water, from the nearest source, after which the snails are thrown on racks in order to drain. The snails are then impaled on thin spills of split bamboo, 20 to 30 specimens on each spill, according to size. The sticks thus filled, are placed over a slow fire of wood embers, for a period of six hours. Next day the sticks are placed in the sun, and sun curing continues until complete drying is effected. During the latter process the bodies shrivel considerably and are eventually about the size of a dried fig.

The sticks, when made up with snails are known as Nwabena. These latter are made up in batches of twenty and formed into a rectangular shape by being woven together with cane in mat-like formation. This formation is known as Nwachem (i.e. Sheet). In this form the drying can be continued as and when necessary, and it is a convenient form for storage and for packing.

## TRIBUTE PAID BY COLLECTORS.

Men, women, and children take part in the collection and preparation. Each family or party work for themselves, on a party basis, rather than a communal undertaking. The collecting area belongs to the Chief of the district who decides on what days collecting shall commence, and close. Any person not an enemy of the Chief may collect snails, but all parties must pay tribute to him. The latter is definitely fixed in all places, and it is one-third of the total catch. Honest persons who declare their catch are permitted to pay in fresh snails, otherwise if caught trying to evade tribute they are compelled to pay in cured snails.

## DISPOSAL AND MARKETING.

Temporary camps are formed in the forest for collecting purposes, and live snails are taken from these camps to the surrounding villages, where the curing is carried out. To these villages purchasers come from considerable distances to buy " Sheets " for retailing in the market towns. The usual price per " Sheet " is 2/6 and this may be regarded as the wholesale value. If the " Sheets " are taken by the collectors to local markets for disposal, the recognised selling price is 4/– per " sheet." Retailers separate the " sheets " and dispose of individual sticks or half sticks, according to local requirements. The selling price of the latter may be as high as 9d and 6d respectively, according to the season.

## ESTIMATED VALUE OF THE INDUSTRY.

The value of the snail industry is difficult to calculate, but is of no mean importance.

In those parts of Ashanti well known to the writer the annual catch is worth about £3,000 to the collectors.

There is, in addition to this, a much larger industry in the Sefwi country worth at least £4,000 per annum to the collectors. Numerous smaller areas exist in other localities and the annual value of these is estimated at £3,000.

The total annual income derived by collectors in all parts of the country is estimated at approximately £10,000.

## NOTES ON THE LIFE HISTORY.

The life cycle of Trade Snails covers a period of approximately three years. The eggs are laid in loose soil, decaying vegetation, or deep growths of moss, always in moist situations which are well protected with natural cover.

The actual period between the laying of eggs and hatching is not known ; but there are two broods per year at intervals of six months and eggs laid in April hatch before the October period, by which time the infants are about the size of a pigeon pea. Hatching takes place during the rainy period, and growth continues while moist conditions prevail, but stops when dry weather sets in. During this latter period the snails secret themselves beneath moist cover and hibernate. It is not until the third year that the snails reach maturity and lay eggs.

Most of the Trade snails die after the egg-laying period in the third year.

*Photo by J. A. C. Holm, Accra.*

WASHING AND IMPALING SNAILS.

PLATE LVI.

*Photo by J. A. C. Holm, Accra.*

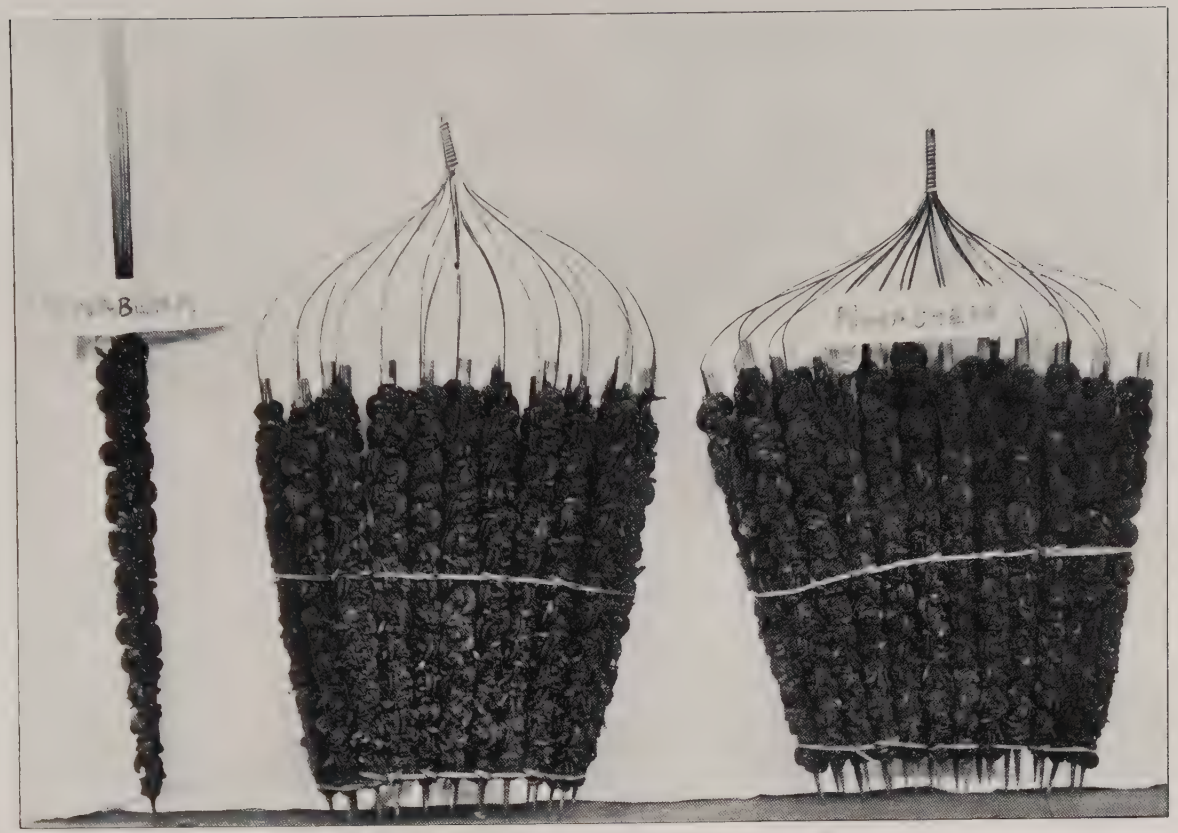


*Photo by J. A. C. Holm, Accra.*

CURED SNAILS READY FOR MARKET.
(Impaled on *Nwabena* and grouped as *Nwachem*.)

Coupling takes place during the early part of both collecting periods, and the eggs are laid towards the close of the same period. The length of these periods is 7 to 8 weeks for the Sun Snails and 6 to 7 weeks for the Regular Snails. The varieties Ottopey, Ottabira and Nwahene live a longer period than three years and continue egg laying after the third year. The males of these varieties are known to live longer than the females.

## PROTECTION OF INDUSTRY.

Throughout Ashanti there are Bye-laws which prohibit the collection of young and immature snails. These laws are rigidly kept, for every one realises the value of the industry and wishes to safeguard it.

## EXTENSION OF INDUSTRY.

Several cases are known to the writer in which attempts have been made to establish new snail areas. This is a costly undertaking and does not always prove successful. Large quantities are collected from a good area, and conveyed promptly to the new locality, where they are distributed to the most suitable spots, and where there is plenty of soft undergrowth and natural cover.

These attempts to establish new colonies are always made with Sun Snails, so as to ensure the full period of rains in order to permit the snails to settle before dry weather sets in. It also permits two egg-laying periods before the drought. New colonies are jealously guarded, and if successful, no collectors are admitted for a number of years. Such attempts often prove futile owing to the presence of natural enemies.

## NATURAL ENEMIES.

The worst of these are Red and Black Driving-ants. These vicious insects attack the snails when they are near maturity, and having killed them will clear every fragment of flesh from the shell. One animal Odompo (a Wild Cat) is known to feed on the larger snails, and for this reason the local people hunt this creature whenever it is seen in a snail area.

## A NATURAL GUARDIAN.

It is of interest to record an alleged natural protector of snails. The Horned Cerastes, known to the people as the laziest of all snakes, hence the Twi name " Borey " meaning, " the sluggish fellow," is said to be known to the snails as their protector. It is a fact that the snake sleeps in a moist quiet spot, and snails are frequently found in close proximity, and sometimes round about it. It is also known that the snake will attack the Odompo which perhaps explains the reason for the country folks regarding this snake as a friend of the snails.

## PAPER No. XXXII.

# MINOR INDUSTRIES IN THE NORTHERN TERRITORIES.

By G. C. COULL.

These notes throw light on many of the methods whereby the people of the Northern Territories obtain the necessaries of life. While not strictly agricultural in nature in the majority of them various plants of agricultural importance are employed and the information given must therefore be of interest to those connected with agriculture.

### TANGA KPAM.

**Shea-butter.**—Made from the kernels of *Butyrospermum Parkii*.

There are two methods of preparing this product.

(*a*) As soon as the nuts are collected they are boiled from one to two hours, in just sufficient water to prevent them roasting. The nuts are then thoroughly dried in the sun and the shells removed. After again drying thoroughly the kernels are ready for storing or making into butter. The kernels are pounded in a mortar, then roasted slowly in an earthen pot, and again pounded in a mortar. They are now ground between stones to a thin paste. The paste is put in a calabash and a little cold water added, the whole being stirred with the hands. Hot water is then added and as soon as the fat appears, cold water is again added till all the fat has risen to the surface; the whole mixture being kept thoroughly stirred all the time with the hands. The fat is now put into another calabash, washed with water, boiled, and left to settle when it is ready for use.

(*b*) When the nuts have not been boiled as soon as collected. The seed coat is removed and the kernels are roasted in a pot with small holes in the bottom of it. The kernels are then pounded in a mortar and ground between stones to a thin paste. The paste is now added to boiling water, and kept boiling, a little water being added from time to time as the paste thickens. When the fat rises to the surface it is skimmed off into a calabash, allowed to settle and is then ready for use.

## DOZIM.

Made from the yellow powdery material in the pods of *Parkia filicoidea*, in which the seeds are embedded.

The powdery material is separated from the seeds, after drying, by being sieved. It is mixed with water to form a paste and is eaten so. This food is only available when the pods are being collected for making kpalagu (dawa-dawa).

## OILS.

These are obtained from palm-nuts and groundnuts.

(a) **Palm-oil.**—The nuts are washed, boiled and then put into a mortar and beaten. They are now washed with the hands and all the kernels and stringy pulp removed. The mass is now put on the fire with cold water, boiled and the oil removed as it rises to the surface. Palm oil is not well known amongst the natives of the Northern Territories.

(b) **Groundnut oil.**—The nuts are beaten in a mortar, roasted, ground to a paste and then boiled. The oil is removed as it comes to the surface of the water. This industry is practised principally in the North of the Protectorate.

## GUMS.

Gum is collected from *Acacia arabica*, after bush-fires when it exudes from the trees. If the tree grows in a village, the outer bark is scraped slightly and a light applied for about five minutes. Next morning the exuded gum is collected. This gum is used for fixing arrow heads to the shaft.

**Gum-resin.**—From *Daniellia thurifera* (*Paradaniellia Oliveri*). A hole about ten inches square is cut in the stem of the tree. This hole is tapered to a point. The hole is now set on fire and allowed to burn for about ten minutes. Next day the gum is collected.

This gum is used for burning in lamps, if no shea butter or groundnut oil is available. It is used on wood as a protection against white ants. It is also used to disinfect clothes against lice. A little is put in a small charcoal fire and the resulting fumes are kept under a cloth which also confines the clothes to be disinfected.

## GOURDS AND CALABASHES.

These are made principally from *Lagenaria vulgaris* (Cucurbitaceae).

For the large calabashes the fruit is cut into halves, the inside pulp removed, and is then ready for use.

A water calabash is made by making a hole large enough to admit the hand. The pulp is removed, and it is ready for use.

Small gourds are cleaned by being buried in the ground for seven to fourteen days till the pulp rots. They are then cleaned out, and so used as water bottles for use on a journey.

Gourds with a long neck are cut into halves longitudinally and then used as spoons or ladles.

The very small gourds are made into ink pots and snuff mulls.

Gourds are also made into musical instruments, or horns for blowing.

## DYE STUFFS.

Dye stuffs are made from a variety of plants, the more important plants only being mentioned here.

**Blue dye.**—This is manufactured from two plants, *Indigofera arrecta*, and *Lonchocarpus cyanescens*, the former being cultivated and the latter growing wild.

(a) **Cultivated dye.**—The leaves are gathered and then put in water and brought to the boil. When just boiling, the leaves are taken out, the water allowed to cool, and left to stand one night. Next morning the water is decanted from the sediment and the sediment again boiled to drive off the moisture. The dye is then ready for use. The cultivated dye is used by the women for dying the hair, and as "blue" when washing clothes. The dye from the wild plant is the one used for dying cloth. The thread of cloth is dipped in the dye the requisite number of times to produce the desired shade of blue.

(b) **Wild dye.**—A pit is dug in the ground, and then beaten hard with a liquid made from steeping the pods of *Parkia filicoidea* in water. The young leaves of the indigo plant are thoroughly beaten in the pit and then made into balls. These balls are put in a basket, another basket put on the top and they are left till next morning. The balls are then covered with mould. They are then sunned for three days. The balls are then broken up and put into water for two days. The mass is put into a basket, covered with with leaves and heavy stones and left to ferment for four to five days, and then dried in the sun for one day. The leaves are now put into a pot of water and left for three or four days. The resulting liquid forms the dye. What is said to be a better dye is made from the pods. The pods are thoroughly beaten in the pit, made into small balls, put into a basket and left for three days. They are again beaten, made into balls and sunned for three days. After this the process is the same as for the leaves.

**Yellow dye.**—Made from the root of *Cochlospermum tinctorium*. The root is bruised and put into water.

**Brown dye.**—Made from the bark of the root of species of *Terminalia*. The bark is pounded and put into water.

These two dyes are not fast. They are used by hunters to dye their coats so that they do not show up in the bush.

**Black dye.**—An almost black dye is produced by dipping the cloth a great many times in indigo. There is no actual black dye.

**Mordants.**—The blue dye is fixed with ash water *Amaranthu* sq. and *Cussonia nigerica*.

## TOBACCO.

This is grown a great deal for local consumption. The leaves gathered, dried about three hours in the sun, then beaten very lightly in a mortar. They are then put into a basket and left about three days. Next the leaves are pounded into small pieces and made into balls. The balls are rubbed with a stick, and then thoroughly dried in the sun for fourteen to twenty days. The tobacco is then ready for use.

**Twist tobacco**—The leaves are gathered and then beaten along the midrib with a stick or small stone, then dried three hours in the sun. Next day they are again dried one hour in the sun. They are then put inside and the next morning twisted into rolls. They are then dried slowly in the sun for about six hours. This slow drying is repeated about five times, and then the rolls are allowed to dry thoroughly in the shade. When dry it is ready for use.

**Snuff.**—This is made from ball tobacco. The ball is cut into slices and ground between stones. It is mixed with saltpetre, sprinkled with a little water and is then ready for use.

## LEATHER INDUSTRY.

The skins of cattle are never tanned, only those of sheep and goats.

**Cattle skins.**—These are scraped on the inside, the hair on outside being left. They are then pegged out and dried hard. When required for use, principally for soles of slippers, a piece is cut off, buried in the ground for a day to make it softer and easier to work, and it is used thus.

**Sheep and goat skins.**—A pot of water is taken and wood ash added. The skin is steeped in this for one night. Next morning the skin is spread on the ground, hair downwards, and the inside, thoroughly scraped. Next the pulp of a pumpkin (non-edible, name unknown) is rubbed into the skin, then dry wood ash is put on top and also rubbed in. The skin is now folded up, hair outside,

## MATERIALS FOR BINDING FLOORS, ETC.

The pods of *Parkia filicoidea* are steeped for three days in water and the liquid is added to the floor while it is being beaten. The pods contain a pectic substance which binds the floor.

For giving a gloss to walls the bark of the tree *Grewia mollis* is used. It is steeped in water, sometimes boiled, and the liquid is mixed with the plaster.

These are the principal substances used for these purposes.

## POTTERY.

This is carried on in some villages and the following is the method of manufacture.

The clay is dug from the ground and dried in the sun for about a week. It is then pounded in a mortar, and ground between stones into a fine powder ; old pieces of pots are also ground and mixed with this powder. Water is now added, the whole being well beaten during the process, till the clay is of the requisite consistency.

The pots or dishes are now moulded and dried in the sun for one day, then thoroughly dried in the shade for three to five weeks. They are then fired for one day. The pot is now dyed red, and is then ready for use.

The red dye is got from a kind of pebble found in the ground It is ground to a fine powder, mixed with water, and then applied to the pot.

If a black pot is required, the dye is applied before the pot is fired.

PAPER No. XXXIII.

# TRIALS WITH COVER CROPS ON KUMASI STATION.

By H. NICHOLAS.

During 1926 and 1927 seeds of various cover crops were received at the Kumasi Station from India and Malaya, and seeds of some local indigenous covers were also obtained. Where necessary these were propagated in the Nursery and then tried out in field plots with other varieties of cover crops which had been grown there for some time.

Exotic Covers.

*Vigna oligosperma* (Sarawak Bean).
*Centrosema Plumieri.*
*Centrosema pubescens.*
*Calopogonium mucumoides.*
*Pueraria thunbergiana* (Kudzu Vine).
*Crotalaria striata.*
*Crotalaria alata.*
*Coix edulis.*
*Hibiscus sabdariffa* (Roselle).

Indigenous Covers.

Krobona White (*Phaseolus Lunatus* variety)
Krobona Red ( „ „ „ )
Apatram ( „ „ „ )
*Sesbania pachycarpa.*
Indigo. (*Indigofera arrecta*).
Neri Red. (*Citrullus* sp.).
Neri White. (*Citrullus* sp.).
Jerusalem Pea. (*Phaseolus trinervis*).

Covers previously grown.

Bengal Bean (*Mucuna utilis* Var.)
Velvet Bean ( „ „ )
*Canavalia ensiformis.*
Soya Bean (*Glycine hispida*).
Pigeon Pea (*Cajanus indicus*).

The members of the last group have been used as cover crops fairly generally on most Stations, and their habits are well known. They are all easily propagated from seed, they seed freely and are quick-growing, and they have therefore justified a certain amount of popularity. They are all, however, far from being the perfect cover crop. None of the surface-covers gives a really close cover ;

they all die down after one season's growth, thus leaving the ground almost bare during the dry season, their rooting habits are not of such a nature as to improve materially the soil tilth, and they do not give a really heavy quantity of material if dug in at their prime as green manure. The erect cover, Pigeon Pea, is a perennial and gives new growth after coppicing, but has the disadvantages that its stems quickly become woody, the proportion of foliage to stem is small and the weight of green stuff provided by coppicing is not great. It also is susceptible to fungoid diseases, causing die-back of the stems and frequently death of the plant particularly after coppicing.

## INTRODUCED COVER.

Among the introduced crops we find examples which appear to have all the attributes except one of the perfect cover crop : (*a*) surface covers which are quick growing, give a close dense mass of cover, with free rooting at all points along the stem, thus improving the tilth, perennial in habit and maintaining growth and succulence through the dry season when they are most needed, besides giving a good weight of material, if used as green manure : (*b*) erect covers which are perennial, deep rooting, give a good weight of succulent material if coppiced for green manure or mulch and which recover readily from coppicing, and show no tendency to die out.

The one drawback against them all is that they are very small-seeded and thus are difficult to propagate ; the soil must be rather carefully prepared before planting, and the seedlings must be nursed during the first few weeks' growth. In the case of Vigna oligosperma it appears that propagation must depend entirely on cuttings, as fruiting is very sparse indeed.

The four following cover crops are selected as showing the greatest possibilities among the introduced crops : *Vigna oligosperma* and *Calopogonium Mucunoidse* among the surface covers, and *Crotalaria striata* and *Indigofera arrecta* among the erect covers.

## SURFACE COVERS.

### A. VIGNA OLIGOSPERMA—(SARAWAK BEAN).

Seed obtained from the Federated Malay States was planted in nursery beds in January, 1928. The seeds were broadcast about 3″ apart and were lightly covered with a dressing of sandy soil. Germination was fair and good growth was made. On May 15th cuttings from these plants were planted 18″ by 18″ in a new nursery bed alongside, and these made very rapid growth, after the first few weeks. Plate LVIII covers four beds, the three beds

VIGNA OLIGOSPERMA AT KUMASI.

PLATE LIX.

Calopogonium mucunoides at Kumasi.

on the right being those seeded in January, and the one on the left being from cuttings in May. It will be observed that by August the beds were indistinguishable, the whole area was densely covered, and all weeds were smothered. Along the borders the Sweet Potato Plant, itself a dense cover crop with considerable penetrative powers, had become permanently established, and here an interesting struggle took place, with honours evenly divided.

**Cover.**—The green cover was very dense with a depth of 6″–9″, and in addition on the older beds there was a layer of leaf mould 1″ thick. A direct estimate of the weight of green stuff available for digging in as manure was not made; in any case this would be small compared with other green manure crops, and would not give a true value for this plant, which is not primarily intended as a green manure. The stems are very slender and the leaves comparatively small. The flowers are very small and inconspicuous, being produced singly underneath the leaf canopy. Attempts to encourage the stems to climb up sticks and there flower and fruit have not been successful. The beds have been examined frequently for ripe pods, but very few have been found. A strong tap root is produced, roots appear very freely all along the stem, and nodule formation is good and the tilth is obviously improved. The plant is said to adopt a perennial habit, and this appears likely here.

**Field Trials.**—Cuttings have been planted out in various plots on the Station, with the following results :—

1. Planted under Amelonado and Cundeamor cacao where there were no permanent shade trees and where the cacao itself was rather weakly, and the ground shade was not therefore dense. The soil was not good and was on the heavy side. Cuttings were planted 5 feet by 3 feet in the middle of June, and did fairly well, a replanting being made in places in July. By October an almost complete mat of green stuff was established in most parts of the plots and shows no sign of determination on the approach of the dry season. Four other introduced cover crops (*Calopogonium*, *Centrosema Plumieri*, *Centrosema Qubescens* and Kudzu Vine) were also tried in similar plots alongside, and these were practically a failure.

2. Cuttings were planted out in August in 1/24th, acre plots at the Rotation area (old corn plots). In the first few weeks these appeared to be establishing themselves well, but during September one plot became a total failure, due apparently to heavy rains, poor drainage and surface wash. In the other plot numerous self-sown Bengal Beans came up, and here the Vigna did fairly well, apparently because the Bengal Bean provided a certain amount of shade and protection from soil wash.

3. In September further cuttings were planted out between lines of Para rubber, and at other places under the cacao. So far the plants are doing fairly well.

It has been found best to establish the cuttings in a prepared bed and to remove a pocket of soil with them when trans-planting. Planting in pockets of "coconut sawdust" with manuring has been recommended in other countries.

**Summary.**—VIGNA OLIGOSPERMA in this Colony does well on unshaded well-drained plots, and fairly well in open field plots when protected by stouter cover plants. It is quite successful under cacao of rather weakly growth, and should be of value in helping to re-establish patches in a cacao farm and in an establishing young cacao. There is not yet evidence that it will thrive under the heavy shade of a good cacao farm. Propagation must depend almost entirely on cuttings since seeding is so sparse; cuttings fairly easily establish themselves.

### B. CALOPOGONIUM MUCUNOIDES.

A small supply of seed from Malaya was planted in nursery beds in September, 1927. Seed obtained here was sown thickly in drills 4 feet apart in a 1/20 acre plot with medium soil in March 1928, a part of this plot being shown in the photograph taken after five months growth.

**Cover.**—The cover is a dense mass from 1 feet to 18" thick, with more than 1" of leaf mould on the soil surface. The plant is of exceptionally strong growth, with hairy stems and is a ready climber, but is more easily controlled than Bengal Beans, and smothers all weeds. It flowers and sets pods freely, the flowers and seeds being very small but the pods take a long time to mature. Roots appear freely at all points along the stem, nodules are numerous and improvement of soil tilth is remarkable. It is said to adopt a perennial habit, chiefly through self-seeding; it shows no sign of flagging on the approach of the dry season.

In September (i.e. after six months' growth) an estimate of the weight of cover was made from a section of the plot. This is given in the following table with other comparative figures:

(i.) 13 tons per acre—*Calopogonium mucunoides*—Kumasi six months growth.
(ii.) 10 ,, ,, ,, —Mixture of Canavalia and Bengal Beans—Kumasi six months' growth.
(iii.) 8 tons 8 cwts per acre—*Centrosema pubescens*—Kumasi months' growth.
(iv.) 5–6 tons per acre—Canavalia—Mauritius.
(v.) 20 ,, ,, ,, —Bengals—Mauritius.
(vi.) 12–14 ,, ,, ,, —Cow Pea—Australia.
(vii.) 25–30 ,, ,, ,, —Cow Pea—St. Hubert.

**Field Trials.—**

1. Seed was sown in pockets under well-shaded cacao. This was a total failure, although germination was good.

2. Cuttings were planted out under patchy cacao with little shade in June 1928; these also were almost a total failure, due primarily to difficulty of propagation.

3. Cuttings have recently been planted out in lines where Para rubber has been cleared, and these show promise.

**Summary.**—*Calopogonium Mucunoides* is a very vigorous surface cover which smothers all ordinary weeds and gives a good weight of material for green manure purposes. The seed is small and therefore in the early stages the seedlings must be nursed. It will grow from cuttings if care is taken. It is a ready climber, and is therefore not suitable for interplanting with annuals except towards the end of the cropping season. It should be useful as a catch-crop for green manuring where the land is left uncovered for an interval of at least three months. In various parts of the world it has been grown successfully as a perennial cover among young rubber, coconuts, and oil palms, and also sisal.

## ERECT COVERS.

### A. CROTALARIA STRIATA.

A small supply of seed was obtained from India in May 1926 and propagated in the nursery. Seed raised from the above was sown thickly in drills 3 feet apart in an open plot with medium to light soil in July 1927. The photograph shows a part of this plot. The seed is very small and the seedlings required care in the early stages. The plants made good growth and started seeding after three months and produced continuously fresh crops of seed, which was collected when ripe. The roots are strong, penetrate to a considerable depth, and are fairly well supplied with nodules. Plants 3 feet high have been found with roots 3 feet deep.

**Cover.**—The plants were strong and bushy with a height of 6–7 feet, the young stems being very succulent. A dense shade was thrown between the rows, which were bare of weeds, and no weeds had been able to grow through the top. The soil was covered with dead leaves, which were continually being shed.

**Field Trials.**—Seed was broadcast with a mixture of Canavalia and Bengal Beans among a standing crop of corn in June 1928, but was a total failure, probably through soil wash. Other sowings in open plots in drills on small ridges have been successful, though there is evidence that the young plants do not stand heavy rains well.

Plots sown in early September on the Ejura Station where lalang grass was plentiful gave after three months a growth of 3 feet—all green, succulent material with dense foliage and throwing a good shade. Lalang, though not completely controlled, was definitely reduced.

Ejura is on the borders of the dry belt and is subjected to a rather severe Harmattan, but after a week of Harmattan these plots gave no signs of suffering, although plots of Bengal and Canavalia Beans grown alongside were flagging.

### B. INDIGOFERA ARRECTA (INDIGENOUS).

Seed obtained from Sampa, N.W. Ashanti was sown thickly in drills 4 feet apart in March 1928, in medium to light soil. The seedlings were thinned to 6" apart, and the plants made very rapid growth. The roots were strong and plentifully supplied with nodules. The plants started seeding very freely from July onwards, the seed being very small.

**Cover.**—The photograph shows a plot with plants 8 feet high, giving a perfect shade, killing out all weeds, and with a soil cover of dead leaves. Part of the plot coppiced in October gave a weight of 8 tons 2 cwts. per acre of green leaves and stems. Very good growth is made after coppicing.

It is reported that where grown by the natives as source of dye, the plants grow to a height of only 4 feet, the leaves being removed from time to time. Other plants are allowed to seed, and these tend to adopt a perennial habit.

**Summary.**—*Crotalaria striata* and *Indicofera arrecta* grow well on medium and light soils. The seedlings are small and require care in the early stages, but under favourable conditions they make rapid growth, and both seed very freely. They give a dense tall cover which effectively kills all weeds. When coppiced they give a good yield of green stuff, both readily recover from coppicing, and withstand spells of drought. Compared with Pigeon Pea, they give a better growth and denser shade; they recover better from lopping, and do not tend to die out as Pigeon Pea does. They would appear useful (1) as soil renovators and cleaners in poor weedy soil (2) for interplanting among young cacao to provide shade and wind protection and to keep down weeds (3) for planting in rather wide circles around oil palm and coconut seedlings.

COPPICED MATERIAL.

1. *Crotalaria striata*—5 tons 16 cwts p.a.—14 months' growth Kumasi.
2. *Indigofera arrecta*—8 ,, 2 ,, ,,— 7 ,,
3. Pigeon Pea —3 ,, 7 ,, ,,—14 ,,
4. *Crotalaria striata*—4 tons 10 cwts per acre 5 months' growth Ceylon.
5. *Indigofera tinctoria*—2–6 tons per acre —India.

CROTALARIA STRIATA AT KUMASI.

PLATE LXI.

INDIGOFERA ARRECTA AT KUMASI.

## COVER CROPS AND CACAO.

Very little appears to have been done with regard to the use of leguminous cover crops among cacao. Pigeon Peas have been grown as a temporary shade and shelter plant among young cacao, and Bengal Beans have been tried in patchy cacao in an attempt to keep down weeds and to aid re-establishing. Both have been only a partial success. The normal course of growing the food crops plaintain and cocoyams among young cacao as a temporary cover is quite successful up to a point. Plantains are very apt to blow over in a tornado, and both they and cocoyams are removed from time to time as their crop matures. As a consequence open spaces appear in the farm and the young cacao suffers from exposure. This is particularly the case after the second and third years, when most of the temporary shade plants have matured their crop and been removed. Also unless the shade is especially good a considerable amount of weeding is necessary.

While still retaining the plantains there appear to be here good possibilities for the use of the cover crops described above. Calopogonium and Vigna could be used as surface covers, while as an alternative to cocoyams Crotalaria would make an excellent nurse plant for the young seedlings. By these means weeding would be reduced, exposure of soil and seedlings would be prevented, fertility and texture of the soil improved, and material for mulch or green manure would be available, and these benefits would be guaranteed for at any rate the first few critical years of the new cacao farm. Vigna definitely is able to tolerate the amount of shade likely to be thrown by a cacao farm up to ten years old and this should be used to provide a permanent surface cover.

## PAPER No. XXXIV.

# MINOR RECORDS, DIVISION OF MYCOLOGY, 1928.

By H. A. DADE.

The fungi marked * are new records for the Gold Coast. Those marked † are newly named.

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Case 476.* *Choanephora cucurbitarum* (B. and Rav.) Thaxter.

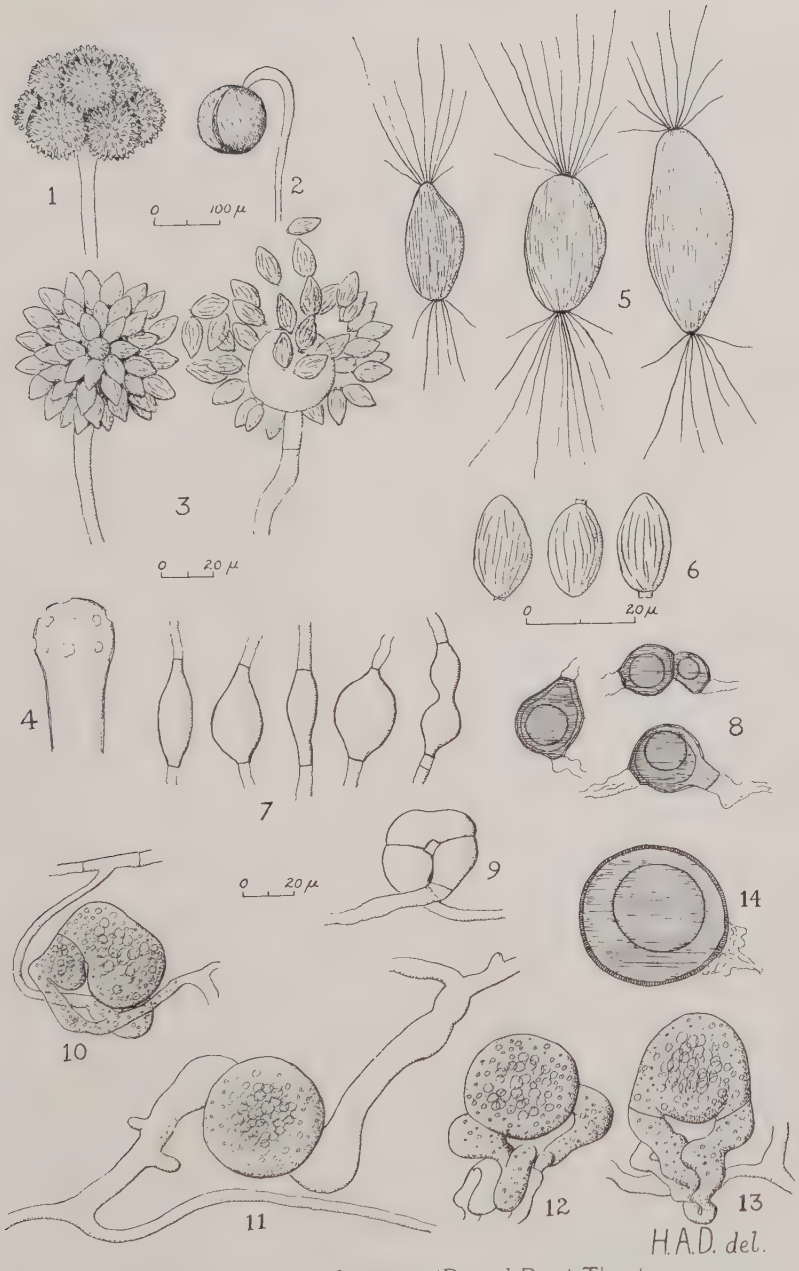
First recorded by R. H. Bunting on rotting paw-paw leaves after a rainstorm at Suhum in April, 1928. Subsequently found in May and June 1928 by Bunting and the writer on cacao husks at Adeiso and on withered blossoms of *Hibiscus* and *Zephyranthes* at Aburi, and as a contamination of plate cultures in the laboratory.

The fungus was probably present on the paw-paw leaves as a saprophyte, for inoculations from pure cultures on paw-paw leaves in the laboratory failed to produce positive results. In the case of the Hibiscus flowers however, conditions indicated that the fungus was responsible for destruction of the flowers.

There appears to be no specific difference between the fungus found and *Choanephora cucurbitarum* (B and Rav.) Thaxter, and this opinion has been confirmed by the Imperial Bureau of Mycology. The Gold Coast form is illustrated by camera lucida drawings in Plate I. LXII.

One feature to which the writer has not been able to find reference in literature is worth recording. This is the regular longitudinal dehiscence of the sporangium, which divides into two equal valves to permit escape of the sporangiospores. This is illustrated in Plate LXII, figure 2 and is the invariable method of rupture of the sporangial wall in the Gold Coast fungus.

In nature the conidial form is far more commonly found than the sporangial form. In most cases sporangia have not been found to occur naturally, but are much more commonly produced in culture than conidia.




*Choanephora cucurbitarum* (B. and Rav.) Thaxter.

Fig. 1. Mature conidiophore normal compound form.
,, 2. Mature sporangium, showing dehiscence.
,, 3. Simple conidiophores formed in hanging drop.
,, 4. Primary vesicle of compound conidiophore, with scars left by detachment of secondary vesicles.
,, 5. Sporangiospores.
,, 6. Conidia.
,, 7. Immature chlamydospores.
,, 8. Mature chlamydospores.
,, 9-14. Stages in zygospore formation.
,, 14 Mature zygospore.

Very abundant ærial mycelium on corn meal agar, not on Dox.

In hanging drops of corn meal and Dox fluid both conidia and sporangiospores began to germinate in 1½ to 2 hours. Germination lateral, one germ tube. Branching of mycelium began after about 6 hours, and chlamydospores were produced shortly after in all cases. Many Chlamydospores put out branches, and none matured in hanging drops.

In hanging drops of corn meal fluid (not in Dox) conidial and sporangial forms were produced from both conidia and sporangiospores. The conidial form produced in hanging drops were simple and unbranched, a single vesicle being produced terminally on the conidiophores, and conidia produced thereon.

Case 486. **Penicillium brevicaule.*

A fungus which is apprently *P. brevicaule* (fig. 2) appeared in cultures made from scrapings of cacao fermenting boxes. It does not take part in the moulding of cacao and is not apparently of economic importance.

**Chaetomium globosum* Kze.

A *Chaetomium* (Plate LXIII. fig. 1) which has been provisionally identified by the Imperial Bureau of Mycology as *C. globosum* Kze. appeared on the plugs of culture tubes and contaminated the medium. The ostiole of the perithecium is surrounded by a thick tuft of spirally curved vivid green hairs.

Case 487. *Sclerotium Rolfsii* on *Pistia stratiotes.*

*Sclerotium Rolfsii* normally attacks land plants in conditions of excessive humidity. Presumably water plants are normally immune from infection. The present case is of interest in that a water plant succumbed to the attack of the fungus.

Plants of *P. stratiotes* were placed in vessels of water in the laboratory and were not immediately thrown out after they had served their purpose. No nutritive material was provided, and after a few days *S. Rolfsii* appeared and destroyed some of the plants. Mud was thrown into the water, and the infected plants which were still alive recovered. The fungus is therefore able to attack *P. stratiotes* in unfavourable conditions of nutrition.

PLATE LXIV.

*Photo H. A. D.*

*Fomes lamaoensis* Murr. Stroma on upper part of trunk of cacao, advancing downwards

Case 494. *Fomes lamaoensis* as a parasite of the aerial parts of cacao.

*Fomes lamaoensis* was found on the trunk of a cacao tree at Anyinam between five and eight feet from the ground. The wood rot induced had caused the collapse of the upper part of the tree at about eight feet from the ground On the fallen part of the trunk fructifications of the fungus were found. The upper part of the standing trunk was invested in the typical matted-hairy stroma of *Fomes lamaoensis*, deep brown in colour in the older parts and white at the lower advancing edges. In appearance the stroma closely resembled the lower forms of sponges, open-mouthed spouts being formed, from which water was dripping. (See Plate LXIV).

† *Marasmius byssicola* Petch.

A hitherto unnamed Gold Coast fungus has now been diagnosed as a new species by Petch in Trans. Brit. Myc. Soc. XII. p. 142, and receives the name *Marasmius byssicola* Petch.

This fungus is " Brown Thread," first recorded by R. H. Bunting and recognised by him as distinct from " White Thread " (*M. scandens*) (see Gold Coast Plant Diseases, Bunting and Dade, p. 52).

† *Ceratostomella paradoxa*. Dade.

*Ceratostomella paradoxa*, the perfect stage of *Thielaviopsis paradoxa* (de Seynes) von Höhnel, by H. A. Dade, appeared in Trans. Brit. Myc. Soc., XIII, pp. 184–194,3 pl.

This article describes the finding, in the Gold Coast, of the perfect (perithecial) stage of *T. paradoxa*, a fungus well known in the tropics as a parasite of coconut palm, pineapple, sweet potato, oil palm, etc.

The identity of the perithecial form with the conidial form is proved, and it is demonstrated that the fungus is heterothallic. The fungus now receives the name *Ceratostomella paradoxa* Dade.

Other new records, all in connection with moulding of cacao, are dealt with in detail by Bunting in Paper No. VIII in this Year Book, and are tabulated here for convenience of reference—

* Case 463. *Mucor sp.* A new species of the Cymo-Mucor group, not yet named.

*Aspergillus fumigatus* Fresenius.

* Case 464. *Aspergillus glaucus* (prob *chevalieri* Mangin).
* Case 471. *Aspergillus ochraceus* Wilhelm.
* Case 473. *Penicillium* sp. not yet named.
* Case 474. *Aspergillus niger*. Van Tieg.
* Case 478. *Absidia capillata* Van Tieg.
* Case 479. *Absidia regneri* (Lucet et Const.) Lendner.
* Case 488. *Circinella spinosa*. Van Tieg et Le Monn.

PAPER No. XXXV.

# RESULT OF DISTRIBUTION OF COTTON-SEED IN WESTERN DAGOMBA DISTRICT, 1927–28.

*Prepared by the Division of Statistics and Surveys, from information supplied by the Provincial Superintendent, Northern Territories.*

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## CONVENTIONAL SYMBOLS.

In preparing the attached map, the convention has been adopted of showing each lot of 10 lbs. of cotton seeds distributed, by a *black* dot. The average quantity of seeds used by the people to plant an acre is 5 lbs. thus each black dot represents sufficient seeds to plant two acres.

In the case of seed-cotton brought in to the Ginnery for sale, each lot of 10 lbs. is represented by a *red* dot. The average yield per acre of seed-cotton is estimated at 15 lbs., thus each red dot represents the yield from two-thirds of an acre.

Motorable Roads are shown in black, with the object of making it clear that lack of production is not directly attributable to want of transport facilities.

Boundaries are shown in red. These are not supposed to be accurate and have been arranged with the sole object of indicating the approximate localities to which seeds were distributed.

Area covered by dots. The area occupied by a dot on a map of very small scale is such that the size of dots must not be regarded as indicating acreage occupied by the crop.

## DISTRIBUTION OF SEEDS.

Various means were adopted for distributing the seeds over an area regarded as within economic reach of the Ginnery. Seeds were in general given to chiefs to distribute among their subjects In some cases supplies were sent to local markets and distributed at random to individuals, and in other cases supplies were given to farmers. By these means seeds were supplied to 426 persons including chiefs, headmen and villagers, who were situated in 386 villages within the localities shown on the map. The number

of recipients quoted above merely serves to show the recorded number of persons to whom the Department issued seeds, and does not include those persons obtaining seeds from their chief. Seeds were issued in quantities ranging from 40 lbs. in the case of Pigu to 812 lbs. in the case of Savelugu. The total quantity distributed being 9,946 lbs., or sufficient to plant 1,989 acres.

In this connection it is interesting to note that Department Officers estimated the total area of cotton which resulted to be 535 acres, which would utilise at most 3,000 lbs. of seeds. Comparing the latter quantity with the total distributed, it may be assumed that 6,946 lbs. of seeds were not used for sowing.

## PROMISE TO PURCHASE CROP.

Recipients of seeds were told that the resultant crop of seed-cotton would be purchased by Government at the fixed price of 2d. per pound, if delivered at the Ginnery in Tamale. It will thus be seen that the people knew it would be possible to dispose of the crop. 40 localities are shown on the map; and of this number 39 received seeds

## RECEIPTS OF SEED-COTTON.

Supplies of seed-cotton were sent in to the Ginnery from 31 localities, the remaining eight made no returns. Quantities of seed-cotton brought in were in all cases far below the potential crop available from the seeds issued. The total amount received at the Ginnery was 4,725 lbs.

The largest contribution came from Lungbungu and the smallest from Kashaw, the weights being 532½ and 28½ lbs. respectively. In this connection it is of interest to record that the former place is over 30 miles from the Ginnery, not situated on a motor road, and the product was man-borne to Tamale. In the latter case the contributing centre is within 20 miles of the Ginnery and adjacent to a motor road. In the case of Sanaregu, to which locality 560 lbs. of seeds were issued, no returns were made to the Ginnery, although the most distant part of same is within nine miles of Tamale, with a motor road running through the locality. Thus it is evident, as mentioned above, that at the moment motor roads do not appear to be the primary factor influencing the cultivation of cotton in the area under review.

## LOCALITY NOT SUPPLIED WITH SEEDS.

When supplies of seeds were being issued it was thought that Gushi was under Diari and would receive an allotment from the Chief of the latter place. When the error was eventually discovered, it was too late in the season for sowing.

## TABULATED DETAILS OF COTTON SEED DISTRIBUTION, PRODUCTION, AND CROP RETURNS.

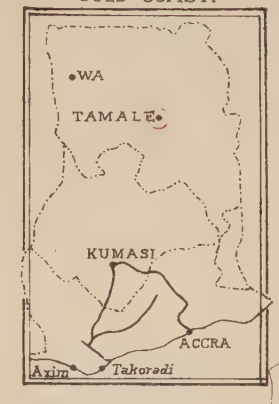
| Name of Division. | Population. | Villages Receiving Seed. | No. of Recipients. | Lbs. Seed Issued. | Estimated Acre Planted. | Seed-cotton Received. |
|---|---|---|---|---|---|---|
| Daboiya .. | 4,931 | 33 | 33 | 160 | 7¾ | — |
| Tolon .. | 6,104 | 22 | 27 | 400 | 39½ | 340½ |
| Kumbungu | 5,150 | 19 | 20 | 251 | 26¾ | 291½ |
| Lungbungu | 1,676 | 18 | 19 | 240 | 45 | 532½ |
| Karaga .. | 1,381 | 24 | 24 | 800 | 25¼ | 280½ |
| Nantong .. | 3,171 | 28 | 28 | 720 | 28½ | 269½ |
| Savelugu .. | 5,037 | 21 | 29 | 812 | 32¾ | 187½ |
| Tali .. .. | 1,036 | 14 | 16 | 160 | 17½ | 161 |
| Voggu .. | 1,898 | 13 | 13 | 165 | 19¾ | 127 |
| Singa .. | 837 | 9 | 9 | 160 | 7½ | 89 |
| Wurribogo .. | 870 | 9 | 9 | 80 | 8 | 79 |
| Niangkwala | 3,047 | 10 | 10 | 240 | 17¼ | — |
| Pwabia .. | 1,960 | 10 | 12 | 240 | 12½ | 98 |
| Diari .. | 1,223 | 5 | 5 | 200 | 5 | 80 |
| Pigu .. | 122 | 1 | 1 | 40 | 3 | 70½ |
| Patengo .. | 998 | 5 | 5 | 320 | 10½ | — |
| Tamale .. | 10,154 | 8 | 8 | 271 | 22¼ | 289½ |
| Burrumani .. | 525 | 5 | 5 | 160 | 7¾ | 94 |
| Bamvim .. | 280 | 3 | 3 | 225 | 9 | 107½ |
| Jantong .. | 519 | 7 | 6 | 160 | 7¼ | 70 |
| Kashaw .. | 1,062 | 12 | 15 | 320 | 13¼ | 28½ |
| Kakpandi .. | 787 | 9 | 9 | 560 | 5¼ | 65½ |
| Jimle .. | 454 | 4 | 5 | 240 | 5 | 70½ |
| Tugu .. | 220 | 2 | 5 | 160 | 6½ | 65 |
| Ga .. .. | 104 | 1 | 1 | 80 | 3 | — |
| Yamalkaraga | 360 | 5 | 5 | 80 | 4½ | — |
| Tampiong .. | 571 | 2 | 2 | 320 | 6 | 33 |
| Zangballong | 673 | 4 | 4 | 51 | 10 | 183½ |
| Dipalli .. | 137 | 1 | 1 | 50 | 2 | — |
| Zugu .. | 728 | 4 | 4 | 126 | 29½ | 268½ |
| Sakwa .. | 66 | 1 | 4 | 80 | 2½ | — |
| Kasuri .. | 1,513 | 8 | 8 | 195 | 14½ | 56½ |
| Bussunu .. | 1,049 | 3 | 3 | 160 | 4 | 49 |
| Zan .. .. | 735 | 6 | 14 | 240 | 14 | 198½ |
| Tibungu .. | 951 | 8 | 8 | 160 | 13½ | 70½ |
| Bullong .. | 2,517 | 18 | 21 | 186 | 23¼ | 331½ |
| Choggo .. | 1,847 | 6 | 7 | 160 | 7¼ | 48½ |
| Zanaragu .. | 1,226 | 10 | 10 | 560 | 7 | — |
| Kanvilli .. | 3,098 | 18 | 18 | 414 | 11¾ | 79½ |
| | 69,017 | 386 | 426 | 9,946 | 535½ | 4,725 |

## CONCLUSIONS.

The attached Table gives details of population, number of villages concerned, number of recipients, quantity of seeds issued, estimated acreage grown in each locality, weight of seed-cotton sent in to Ginnery.

The estimated acreage under cultivation was calculated to produce 8,025 lbs. seed-cotton. Since the total weight received

GOLD COAST.




## REFERENCE.

A BLACK Dot = 10 Lbs. SEEDS DISTRIBUTED.

A RED " = " " SEED-COTTON RET'D TO GINNERY.

— MOTORABLE ROADS

1. Tolong
2. Wurubogga
3. Burrumani
4. Choggo
5. Kamvilli
6. Sanarego
7. Tamale
8. Bullung

COTTON DISTRIBUTION IN WESTERN DAGOMBA DISTRICT 1927-28.

MAPS NORTH C-30/Q & NORTH C-30/R

Pigu
Diari
Karaga
Dipalli
Gushi
Ga
Patenga
Singa
Savelugu
Tibungu
Zugu
Lungbunga
Zangbalung
Voggo
Sekwe
Yamalkeraga
Kasuri
Tampiong
Daboiya
Kumbungu
Nantong
Sung
Tali
TAMALE
Tugu
Jimle
Niankpwala
Bamvim
Busunu
Kashaw
Janton
Pwabia
Kakpani

Survey H. Q. Accra, 1929.

at the Ginnery was only 4,725 lbs. the remaining balance of 3,300 lbs. must have been disposed of elsewhere, and we may assume, more profitably. Information on this point however is conflicting and needs further investigation.

Lack of production and disinclination to sell to the Ginnery, is alleged to be due to the local system whereby a Chief receiving seeds for distribution is said to claim the crop derived therefrom. If such were the case it would appear the growers get nothing in return for their labour. On the other hand it must be admitted that in cases where seeds were issued direct to farmers, we have no record of these persons returning seed-cotton to the Ginnery. The explanation offered in the latter case being: Government having supplied seeds, any money derived from the resultant product would be claimed by the Chief.

An active propaganda campaign is clearly indicated, if production is to be substantially increased; and this will need to be carried on over a number of years if an industry of commercial value is desired. It is suggested that Political Officers might continue to give their assistance in this connection, and aim at making the scheme known to individuals rather than the Chiefs. Efforts to increase production should be directed in general, to those centres which returned seed-cotton to the Ginnery. These latter should receive supplies of seeds, before issues are made elsewhere. Whenever possible seeds should be issued to individuals, rather than to the Chiefs. For some years to come all efforts should be concentrated on establishing a cotton industry within the area shown on the map, as beyond such radius producers would not be within economic reach of the Ginnery.

## PAPER No. XXXVI.

# ECONOMIC BOTANICAL PROGRAMME.

By T. LLOYD WILLIAMS.

Economic Botanical Work was recommenced in January, 1928.

As most of the work in hand requires one or more years before even preliminary results can be given, it is proposed in this article to give an outline of the main items of work being done together with the methods being used, and to refer only briefly to any results already obtained.

## A. COTTON.

The aims of the work in hand may be summarised as follows :—

(*a.*) to select and breed suitable varieties.

(*b.*) to try out as many new varieties as possible.

(*c.*) to obtain a knowledge of the reaction of the crop to its environment and of its response to different treatments.

(*d.*) to obtain an estimate of the total damage due to disease and pests and of the damage due individually to each of the more serious diseases and pests.

### (a) Breeding and Selection.

The method used is to select superior plants of any particular variety in the field and then by means of inbreeding and selection to isolate superior strains.

The selection is made on a score card basis.

The following is the basic score card used :—

A. Vegetative Characters (20).

| | |
|---|---|
| Habit .. .. .. .. | 10 |
| Disease Resistance .. .. | 10 |

B. Lint Characters (50).

| | |
|---|---|
| Length .. .. .. .. | 25 |
| Regularity .. .. .. | 4 |
| Strength .. .. .. .. | 7 |
| Ginning .. .. .. .. | 10 |
| Texture and Colour .. .. | 4 |

C. Yield (30).

This score card is modified to suit local conditions, e.g. in the Northern Territories "leaf curl" is a serious disease. As highly resistant strains can be obtained by breeding, any plant that suffers from this disease is thrown out.

The following are some of the most important characters in the cottons chosen in the 1927–28 season :—

Togoland.

| *Sonko No.* | *Lint Length* $\frac{1}{16}$ | *Ginning %.* | *Points of a possible hundred.* |
|---|---|---|---|
| *22H | 17.3 | 30.7 | 63 |
| 6 | 16.8 | 32.6 | 58 |
| 3 | 17.2 | 35.2 | 57 |
| 2 | 16.7 | 35.5 | 54 |
| 16 | 17.0 | 34.7 | 53 |
| 14 | 16.3 | 34.6 | 41 |

*Probably a hybrid Sonko × Kadeanygba.

| *Ishan No.* | | | |
|---|---|---|---|
| 8 | 17.2 | 34.2 | 60 |
| 17 | 18.0 | 30.8 | 52 |
| 9 | 16.9 | 31.1 | 48 |
| 11 | 17.5 | 27.7 | 48 |
| 19 | 17.4 | 30.9 | 47 |

Northern Territories.

| *Allen No.* | | | |
|---|---|---|---|
| 14 | 18.2 | 33 | 59 |
| 43 | 17.3 | 31 | 54 |
| 25 | 18.6 | 31 | 52 |
| 24 | 18.4 | 32 | 48 |
| 15 | 15.6 | 29 | 46 |

Thus it will be seen that the best Allen strains have a slightly longer lint than Ishan and Sonko, but a lower ginning percentage.

A certain amount of difficulty was experienced in finding a rapid, simple and accurate method of measuring lint length.

The following methods have been adopted:—

1. For the preliminary selection of a large number of individual plants. The seed cotton from each plant is well mixed, a definite number of seeds taken at random, the lint pulled and combed, and then measured in three positions. This method was found to give quite comparable results with different workers. The figures thus obtained are only comparative and do not give the true mean lint length of the cotton.

2. The preliminary selections having been made, firstly on yield and then on lint length, obtained as above, are now examined in more detail. The mean lint length is determined by the paraffin slide method. In this method a sample is taken from the lint, and one hundred hairs are individually measured on a graduated glass slide moistened with paraffin. This method is accurate, but very slow and also involves eye strain, so it is hoped to obtain a Balls Sledge Sorter for the 1929–30 season.

The ginning percentage is, at present, obtained by hand, as no hand gin suitable for dealing with individual samples is available at present.

Regularity, strength, texture and colour are at present estimated but later it is hoped to obtain an apparatus to determine strength and also to determine hair weight per centimetre.

During the 1928–29 season most of the cotton work is being concentrated in the Northern Territories.

The general plan of selection is the plant to row method and works as follows :—

1*st year* (1927–28). Preliminary selections in the field.

2*nd year* (1928–29). The selected plants are now planted out in rows. Each row consists of the progeny of a single plant. Each plant in each row is numbered. The date of the first flower and the position of the first flowering node have been noted. All the flowers are selfed daily and a record kept of the number of flowers produced by each plant. Thus as the bolls are individually harvested—and classified according to the number of locks, accurate shedding records will be available for each plant—which is of great immportance, especially in the Northern Territories.

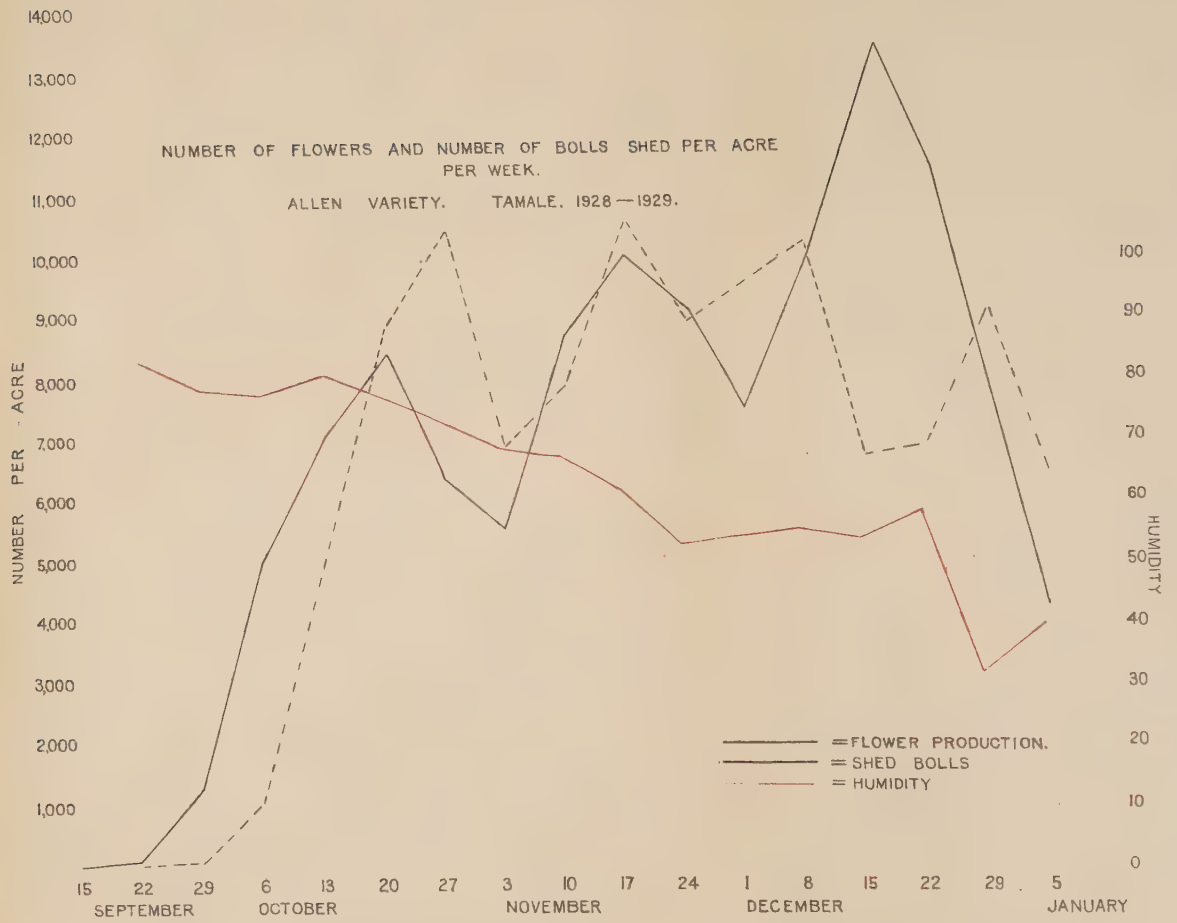
3*rd year* (1929–30). The best plants from the 2nd year will be selected on a modified form of score card, more weight being given to shedding percentages. The cottons by now will have attained a reasonable degree of purity and will be arranged to form a modified form of yield trial as well as a selection plot in this season.

4*th year* (1930–31). The selected cottons from the third year will be multiplied and tested out on a field scale.

5*th year* (1931–32). A limited amount of seed will be available for distribution under strict control and thus a seed supply will be available for the 6th year.

Each year new selections and re-selections will be made and these will be treated in the same way.

Plate LXVI




Survey H. Q. Accra, 1929.

(*b*) **Varieties.**

The main varieties at present being grown are, in Togoland, Sonko and Ishan and in the Northern Territories, Allen and Ishan. One native plant of the Gumanli type was selected in 1927-28 and whilst it is not thought that it will be possible to isolate a good strain from the local native varieties, they are being used to hybridise with Allen, and the progeny will be tried in the 1929–30 season. Arrangements are also being made to try out as many new varieties as possible next season.

(*c*) & (*d*) **Physiology and Disease Incidence.**

These are being studied by means of sample plots of either $\frac{1}{8}$ or $\frac{1}{5}$ acre, 30 plots having been laid down. All the plots are double, i.e. one half is used for the physiological experiments and the other half for a weekly stainer index. The plots are distributed over the cotton being grown at Tamale and also include four at Yendi.

The following work is being done on these plots :—

(*a*) Daily flower counts.

(*b*) Daily collection of shed buds and bolls.

(*c*) Collection and classification of open bolls.

The sheds are classified according to the cause of shedding, i.e. physiological causes, boll worm damage, stainer damage, and other injuries which here comprise mainly disease damage.

A stainer count is taken on each plot once a week in order to obtain the stainer index. Both boll worms and stainers are classified, as far as possible, according to species.

Figures for the whole season cannot yet be given but it may be stated that shedding percentages are abnormally high and that boll worm figures and bacterial diseases are serious.

Plate LXVI will show the progress of this work to date as regards flowering and boll shedding.

*Explanation of Graph.* This shows the number of flowers produced and the number of bolls shed on the main area of Allen at Tamale Experimental Station. These figures are taken from the sample plots on this area and expressed as the number per acre. It will be noted that the flowering curve shows three well defined peaks and the shedding curve four peaks. The average weekly humidity is given in order to show the great influence of the Harmattan on flower production. It will be noted that until the Harmattan started (Nov. 24th) the shedding curve followed the flowering curve very closely with an interval of a week, but after that date the curves are quite dissimilar.

It will be seen that the shedding percentage is very high and to date it works out at 84%.

The following experiments are also in hand :—

(i) Rate of growth. Plants from each series of plots in the optimum time of planting experiment have been selected at random and their weekly rate of growth is being determined.

(ii) Experiments to determine the period from flowering to maturity. Approximately 40 plants picked at random have had all their flowers marked once a week with small dated zinc labels. These plants are inspected daily and the date on which the bolls ripen is recorded. To date the period for Allen has varied from 41–50 days with a mean of 45 days.

## B. CACAO.

So far opportunities for work on this crop have been limited. An experiment on budding of cacao in collaboration with the Horticultural division is now in hand.

The main lines of the experiment are as follows :—

The trees that have been individually recorded over a period of years at Aburi and Assuansi (see 1927 Year Book) have been examined and the twenty best trees from each station selected, taking into account, health, regularity of yield, distribution of pods on the tree and the soil and shade conditions under which the tree is growing. It is known that the behaviour of budded cacao is very similar to that of budded rubber, in that there is not necessarily any correlation between the yield of the mother tree and of the vegetative offspring, and that certain mother trees with a high yield will have low yielding offspring, whilst others, many fewer, will have high yielding offspring, and that these characters are permanent. Hence it is proposed to bud these 40 mother trees on to enough stocks to produce 20 budded trees from each mother tree. Half of the resulting trees will be planted at Kpeve and half at Kumasi. The trees will be planted in an arrangement that will give statistically sound results.

As cacao has the habit of dimorphic branching, buds from a fan type branch producing a low spreading tree with a monomorphic habit, and buds from a chupon the usual type of tree, it is proposed to bud half the trees with fan type buds and half with chupon buds.

It is also intended to lay down other experiments on the following lines :—

(*a*) Replacing poor yielding trees in an established plantation by cutting back and budding and grafting, and by replanting.

(*b*) On other methods of vegetative reproduction especially with a new method of root wiring that has been successful with temperate region crops.

## C. OIL PALMS.

The two Oil Palm Experiment Stations at Obuasi (Eastern Province) and Anaji (Western Province) have been placed in Charge of the Division of Botany for botanical work.

The experiments detailed below have been laid down at both hese stations.

(a) **Germination Experiments.**—The usual methods of germination practised are slow ; and often result in a low percentage of seed germinating.

In view of the selection work in hand and of the recent importation of seed from the East Indies, experiments have been laid down in order to find a reliable method that will both hasten germination and give a good percentage germination.

The method used by the Dutch in Sumatra, planting out at definite intervals in nursery beds, has proved very unsatisfactory in this country.

The method of germinating under glass, whilst satisfactory at Accra, has been useless elsewhere, possibly on account of lack of watering and attention. This, however, is being repeated, covering up the sides of the bed with thatch, as far as the glass, thus making in effect a forcing box. Mr. Howes' experiments showed that planting in boxes gave very poor results and he obtained the test results by planting nuts heaped up in small trenches.

It is thought that the main factor in obtaining good and rapid germination is a constant high temperature plus a constant high degree of moisture.

The experiments below have been designed with this end in view.

The nuts are being sown in small trenches, both with and without humus, and also as a control, in the ordinary nursery beds. Various treatments to hasten germination such as soaking in cold water and heating daily up to 130°F and 160°F for a fortnight are also being tried. The experiments are also being repeated with thick and thin shelled nuts and undepericarped and depericarped nuts. Half the beds and trenches have been covered with a thick layer of palm leaves and straw in order to conserve moisture.

It has been reported that if an entire bunch of fruit is planted, germination is rapid and quite satisfactory. This is being confirmed.

(b) **Collection and Classification of Varieties.**—A considerable number of types of oil palm has already been collected, but it is not possible to propose any system of botanical classification at this stage.

However, at present, for all practical purposes, the native classification (see 1926 Year Book) depending only on the fruit (except in the case of Abehene—King Palm) is useful.

(c) **Selection and Breeding.**—Selection of good types and high yielding trees is the first step. A certain number of trees of known variety had previously been marked on both stations and their yields individually recorded. This work has now been greatly extended. It has been decided to concentrate on breeding a type, which in the native classification, may be described as Adibe—a sub-type of Abobobe. The shell in this type is considerably thinner than in Deli, but not thin enough to cause difficulties in extracting of oil or in the seperation of the kernels.

Several trees of this type have been isolated and are now being pollinated or crossed. One bunch was analysed by the Chemist and gave the following results :—

| | |
|---|---|
| Clean fruit .. .. | 59.1% |
| Stalk, chaff, etc. .. .. | 41.9% |

The clean fruit contained :—

| | |
|---|---|
| Oil .. .. .. .. | 34.1% |
| Fibre .. .. .. | 14.2% |
| Kernel .. .. .. | 8.7% |

The method of artificial pollination used is to clear the leaf stalk from around the female inflorescence about a week before it is due to flower.

A few days later a green Willesden canvas bag with a double thickness of butter muslin at the top in order to provide a certain amount of aeration, is tied around the base of the female inflorescence. The pollen is collected as opportunity arises and is stored in desiccators where it will keep for at least two months. The flowers are pollinated on two successive days by shaking the desired pollen over them, after temporarily removing the bag, which is finally taken off a few days later.

Satisfactory results are being obtained by this method and control experiments show that the amount of accidental pollination is very small.

(*d*) **Miscellaneous.**—Experiments to determine the rate of growth of oil palms by finding the rate of leaf formation are also in hand. Several sterile palms have been isolated and the causes of sterility are being investigated.

## D. SHEA.

The question as to whether there are definite botanical varieties of shea is being investigated with special reference to the question of the unsaponifiable matter in the fat.

It has been suggested that the percentage of unsaponifiable matter may vary between the different varieties and hence offer scope for selection from this point of view.

A large number of shea trees have been examined both at Tamale and Yendi and a considerable amount of variation noted, especially in leaf and fruit characters. Leaves, flowers and fruits are being collected from a number of marked trees. The fruits will be analysed and the percentage of unsaponifiable matter determined.

If the preliminary results justify it, breeding experiment will be laid down to confirm the existance of distinct varieties.

## E. ECOLOGY.

One branch of ecology, i.e. the use of plant indicators of different types promises to yield valuable results. A start has been made on the collection of different plant indicators as regards cacao and the preliminary results obtained to date indicate that this work will yield interesting results.

A study of the fodder grasses in the Northern Territories will be commenced next season, both from the point of view of food value and of the establishment of pastures of the better varieties. Various other small investigations are in hand, including the collection of plants that may be of possible economic value, especially medicinal plants or plants that may be of use as cover crops. Arrangements are also being made to import new and promising varieties of various economic crops, especially cotton, maize and bananas.

These investigations, however, have not progressed sufficiently to be reported at this sage.

# PAPER No. XXXVII.

## FIELD EXPERIMENT.

By W. HORTON BECKETT.

Increasing importance is being attached to exact methods of experimentation in the field, parallel with the development of statistical method in its application to experimental science. A difference in yield, or in a physiological characteristic, recorded between two plots of different varieties of a crop, or of the same variety differently treated, is no longer considered significant. Replication of plots and statistical analysis of the data are now generally accepted.

This new era in the analysis and interpretation of plot data is comparatively recent. A paper by Hall in 1909 and another by Wood and Stratton at Cambridge in 1910 set the ball rolling, and almost simultaneously there appeared papers by Wood, Mercer and Hall, Hall and Russell, and Pickering and Collins, three of which were published as a supplement to the Journal of the Board of Agriculture in 1911. There has been steady development in technique of experimental lay-outs and of analysis of plot data since 1911; the most revolutionary contribution is perhaps during the last ten years with the application of the analysis of variance (Q.V.) to plot data by R. A. Fisher at Rothamsted. The theory of analysis of variance is older than its application to plot data,, and is mentioned in papers by Student, J. A. Harris in America and Fisher, of earlier dates, but its application to plot work affecting both the technique of lay-out, and analysis of the data, is due to Fisher, and is steadily resulting in a change over from systematic to random arrangement of plots in the field.

The mass of literature, both British and American, which has accumulated during the last decade is not readily available to the officer of a Tropical Department of Agriculture, and moreover, the subject has become so specialised that a close study must be made of the statistical methods employed if the theory underlying modern field experiments is to be understood; a study which the average officer has neither the time nor the facilities to pursue. The present article is an attempt to pull together this scattered information and to suggest the applications of these modern methods to our local conditions. In a short article it is impossible to go into detailed lay-outs and their analyses, for which the reader must be referred to the original references given. The general outline only is given here, but subsequently it is hoped that a fairly comprehensive summary of the subject will be published as a bulletin.

## HISTORICAL.

An idea of the development of the technique of field experiments and the analysis of data can be more readily obtained by a perusal of the appended bibliography of literature, than could be expressed in a short survey. The philosophical background of this development is however of peculiar interest. From time immemorial the tiller of the soil has divided his field into two halves and tried different cultivations, or different varieties of his crop, for his own education. With the development of Agriculture as an industry the natural outcome was the definite laying down of anexperiment designed to answer a particular question for the benefit of that industry. In England this began with the classical experiments laid down at Rothamsted in Hertfordshire by Sir J. B. Lawes associated with Sir J. B. Gilbert in 1843. This was a side by side arrangement of single plots, which were repeated year after year on Broadbalk. In 1852 a chess board arrangement was used in laying down the Hoos field Barley experiments. There was no replication of similarly treated plots, but observations were systematically made year after year, giving repetition in time. It was soon realized that the subject of field experiment was complex and that an apparently uniform field was made up of different fertility values ; an experiment in which one treatment occurred on only one plot would be vitiated by the different fertility levels of the different single plots. It was assumed that the change in fertility across a field, or down a slope was more or less uniform and alterations were made in the strip and the chess board experiment to compensate for the fertility gradients. The treatments were replicated in each experiment, marking a distinct step forward in the technique.

The number of strips or plots in the chess board were arranged on a definite plan to reduce the effect of the difference in fertility. Strip experiments were " balanced " so that the sums of the distances of the plots under one treatment from a fixed gravity line was constant.

With the multiplication of the number of varieties or treatments under test a system of " control " plots was used, by which each experimental plot was compared with one or more control or " standard " plots. The grading of the fertility from one control to the next was studied, and many attempts were made, especially by American workers, to reduce to formula the expected yield of the experimental plots, had they been under control or " standard " treatments. The actual yield would then be compared with the calculated yield. The values were calculated on regressions or on interpolated values between controls. Much ingenuity was displayed in the analysis, but with further appreciation of statistical methods a reluctance to use these calculated values (or to use Student's term, values which savoured

of " cooking ", caused them to be abandoned. The idea of linear soil heterogeneity was given up and studies were made on uniformity trials to investigate its true nature. In 1908 Student's paper on the " Probable Error of the Mean " in Biometrica, followed by the papers cited above marked the beginning of an intensive study of statistical methods in analysing the data from plot yields. With the use of standard error calculations in published data, it was natural for attempts to be made to determine the actual value of the error in field experiment, and early workers tended to define the error as a definite fixed percentage of the yields. It was then found that the error differed with the size of plot, and investigation into the plot size began, again with the tendency of defining a definite optimum size of plot.

The great step forward occurred when it was pointed out by mathematical statisticians who had interested themselves in Agricultural experiments, that the standard error concept depended on random sampling and normal distribution, and that the value calculated from a few plot yields was only an estimate of the true standard error, and that the calculated values could give no valid test of the significance of a result when the arrangement of the plots was systematic. This marked the beginning of randomization in plot work. By this time the mathematics used in the analysis had become involved and the advanced nature of this statistical analysis interested mathematicians in all countries where field experiment was conducted. Fisher at Rothamsted surveyed the whole field and developed the analysis of variance methods for plot work. Thus at the present time, plot experiment has developed into an exact science.

## LAYOUTS. BASIC FORMS.

(*a*) **Strip Methods.**—The simplest form ABABAB in a comparison of two varieties or treatments has the fault of having the A's always on the same side of the B's, introducing a systematic error if there happens to be a fertility gradient across the plots. The arrangement —| ABBA | ABBA |—was an improvement by Beaven and forms the basis of his half-drill strip method, now used at the National Institute of Agricultural Botany at Cambridge It is peculiarly suited to drill-sown cereal trials as the seed drill may be filled with the varieties in separate halves of the hopper, and the ABBA arrangement is produced in one complete journey up and down the field. The only form of layout, however, giving a valid estimate of error is one in which the arrangement is arrived at by randomization. In this case the | AB | unit would be decided by the toss of a coin, or other random method, and each unit arrived at separately as

| AB | AB | BA | AB | BA | etc.

With more than one variety the method is complicated. ABCDE ABCDE would be bad. To improve this "balancing" was resorted to as in

| C | A | D | E | B | E | A | B | D | C | B | D | C | E | A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| −7 | −6 | −5 | −4 | −3 | −2 | −1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

If distances are measured from the centre of gravity, 0, it will be seen that for each treatment, the sum of the distances is equal to 0. The C's have $-7+2+5=0$; the A's $-6-1+7=0$ and so on. The best arrangement would be to obtain the order of the letters ABCDE at randon for each set as by drawing lettered cards from a hat (producing thereby randomised blocks, which are dealt with below).

(*b*) **Chess Boards.**—The same ideas as for strips, apply to chess boards. Several forms are in general use.

*Simplest Form.* *Repeating Form.* *Balanced Form.*

——————gravity line.

| | | | | |
|---|---|---|---|---|
| A D | A D | A E C. | 1. | A C B D |
| B E | B E | B F D. | 2. | C A D B |
| C F | C F | C A E. | 3. | B D A C |
| | | D B F. | 4. | D B C A |

In the balanced form the sum of the distances of any one letter from a gravity line at the top of the arrangement is constant. For A it is $1+2+3+4=10$; for B, $3+4+1+2=10$ and so on.

(*c*) **Random Arrangements.**—There are two forms in use at present—the randomised block, and the Latin Square, invented by Fisher at Rothamsted. In the randomised block system the complete set of treatments is randomised for position separately for each block of treatments.

| | | |
|---|---|---|
| B E | E C | D E |
| A F | B A | B F |
| D C | F D | A C |

The order in the block is arrived at by drawing lots or shuffling cards. The strip method mentioned at the end of section (*a*) above is a randomised block arrangement. The size and shape of the blocks are inmaterial.

The Latin Square is an arrangement in which each row and each column contains the whole set of treatments. It is equivalent to two simple randomised block systems superimposed at right angles.

| | | | |
|---|---|---|---|
| A | B | C | D |
| B | D | A | C |
| C | A | D | B |
| D | C | B | A |

The arrangement appears at first to be systematic and not random, but the method of arriving at the arrangement is all important. If all the possible arrangements complying with the conditions (that each row and each column contains each treatment once), were written out on separate cards, the pack shuffled and one selected at random, the arrangement is valid. The arrangement arrived at is one selected at random out of the total possible arrangements.

The Latin Square can be used for any number of treatments, though for large numbers it becomes unwieldly, and as yet insufficient large trials have been made, to advocate their use. Where complete sets of arrangements are not available, a random arrangement may be arrived at as follows. Take lettered cards equal to the number of treatments, and pick out one at a time, giving the first now :—

BAEDC in a 5 x 5 Latin Square.

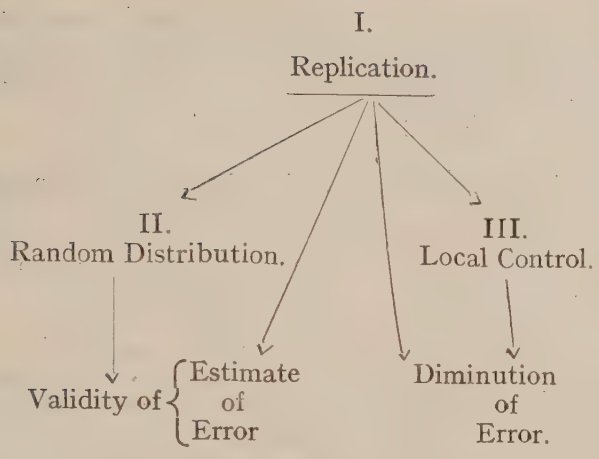
The first letter of the next row may be any except B : let it be D :—

| | | | | |
|---|---|---|---|---|
| B | A | E | D | C |
| D | . | . | . | . |
| . | . | . | . | . |
| . | . | . | . | . |
| . | . | . | . | . |

The next letter cannot be D or A, so select one at random of the three possible letters. Carry on this process until the square is completed. Now rearrange complete rows at random, by shuffling 1, 2, 3, 4, 5, and arranging the rows in the order they come (say 41253). This rearrangement does not affect the conditions of rows and columns containing each letter once. Repeat the process for the columns. The resulting square can be said to be completely random. To make every possible radomiation, repeat for direction. That is by looking at it from the four sides, N.S.E. or W. Select one at random and use it as the base. The only remaining possibility is the reflection—by turning the square over bodily.

## ANALYSIS.

Before briefly discussing the analysis of the layouts mentioned, the principles may best be appreciated by a diagram, hitherto unpublished, drawn up by R. A. Fisher, for demonstration purposes in the statistical laboratory at Rothamstead.




The following statistics will be used.

1. $\bar{x}$ Mean.
2. s Standard Deviation (an estimate of the true standard error, sigma).
3. $s_m$ Standard Deviation of a mean.
4. $s_d$ Standard Deviation of a difference.

$$\text{Mean of a set of observations} = \bar{x} = \frac{\Sigma(x)}{n}$$

$$\text{Standard deviation} = s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$$

$$\text{Standard deviation of a mean} = s_m = \frac{s}{\sqrt{n}} = \sqrt{\frac{\Sigma(x-\bar{x})^2}{(n-1)n}}$$

$n-1$ is used in S.D. formula as only $n-1$ observations can take an arbitrary value, if the mean is fixed. There are $n-1$ degrees of freedom among the n observations.

S.D. of a difference $= \sqrt{s^2_a + s^2}$ for independent observations but a correction $-2rs_as_b$ must be made if there is correlation between the sets of observations. A method known as " Students " method gets over this $-2rs_as_b$ difficulty by taking the standard deviation of the differences of each pair of observations. If the two series are $x_1$, $x_2$, $x_3$, etc., and $y_1$, $y_2$, $y_3$, etc., the S.D. of the series $(x_1-y_1)$ $(x_2-y_2)$, etc., is calculated. If this method is analysed, it will be found that it cuts out the $-2rs_as_b$ part of the formula. Space forbids the mathematical analysis here.

This is the common method of analysing a strip experiment of two varieties or treatments. The mean difference is tested for significance by the standard deviation calculated, by looking up the value found for $\frac{D}{S_d}$ in a probability table.

In certain strip experiments, as in simple or compound "control" arrangements,

| | |
|---|---|
| X A X B X C X A X B | X A B X B C X C A X A B |
| Simple Control | Compound Control |

experimental plots (ABC) are often compared only with the adjacent or mean controls (X.X.). An example of the simple control method is used by Faulkner, where the treated plot is compared with the mean of adjacent controls, and the error figure calculated from the controls only. These methods are open to the objection that the estimate of error used in testing significance is not a valid estimate.

For a chess board, Engledow and Yule developed an analysis giving an estimate of the S.D. of mean difference and a short method of calculating it. The S.D. ($s_d$) is then used for testing the significance of mean differences between treatments.

If $_d$ is the quantity required and $m$ and $n$ the number of treatments and replications respectively; the following statistics are calculated:—

(1) $S_r^2$ = mean variance of a treatment round its own mean.

$$= \sum_{1}^{m} (x - \bar{x}_m)^2 \div (mn - 1)$$

where x = an individual reading

and $\bar{x}_m$ = mean of one treatment.

(2) $Sp^2 = \sum_{1}^{n} (\bar{x}_n - \bar{x})^2 \div (n - 1)$ = variance of means of plots in each series.

where $_n$ = mean of one series

$\bar{x}$ = general mean.

The identity worked out by Engledow and Yule is then

(3) $$S_d^2 = \frac{2m}{m-1} (S_r^2 - S^2)$$

thus reducing the large amount of arithmetic required in the direct calculation of $S_d^2$ for which ALL possible differences must be used.

For a randomised block, or Latin Square, arrangement the analysis of variance method is used. The variance of a series of observations is the square of the standard deviation. The method consists in calculating the total variance between all the plots, and then partitioning it out into the contributions due to blocks, or rows and columns, varieties or treatments, and the remainder due to all other errors, which we require for making significance tests. The Latin Square will be taken as an example. The steps in the analysis are as follows :—

If $N$ = number of plots.

$n = \sqrt{N}$ = number of rows, columns, or treatments.

(*a*) Find sums and means of all plots $\Sigma(x)$ ; $\frac{\Sigma(x)}{n} = \bar{x}$

Find sums and means of columns $C_1, C_2$ ; $\bar{c}_1, \bar{c}_2, \bar{c}_3$,

Find sums and means of rows $R_1 R_2$ ; $\bar{r}_1, \bar{r}_2, \bar{r}_3$,

Find sums and means of treatments $T_1 T_2$ ; $\bar{t}_1, \bar{t}_2, \bar{t}_3$

(*b*) Total sum square difference $= \Sigma(x-\bar{x})^2$ where $\bar{x}$ is general mean.

$$= \Sigma(x)^2 - N(\bar{x})^2.$$

(*c*) Sum square difference of Rows $= \frac{\Sigma(R)^2}{n} - \frac{(\Sigma x)^2}{N}$.

Sum square difference of columns $= \frac{\Sigma(C)^2}{n} - \frac{(\Sigma x)^2}{N}$

Sum square difference of treatments $= \frac{\Sigma(T)^2}{n} - \frac{(\Sigma x)^2}{N}$

(*d*) Calculate variance for total, rows, columns, treatments, etc. $= \frac{\text{Sum square differences.}}{\text{degrees of freedom.}}$

(*e*) The requisite degrees of freedom are one less than the number of observations in each case, as the mean is fixed in calculating the differences. For total variance, the number of degrees of freedom, is $N-1$ ; for columns, rows, or treatments $n-1$, and therefore for the remainder $N-1 - 3(n-1)$. The difference between the total sum square difference and the total of the sum square differences for the rows, columns, and treatments is the remainder used for obtaining the Standard Error of mean difference. The residual variance is obtained by dividing this remainder by the requisite degrees of freedom, $N-1 - 3(n-1)$.

The Standard Error of difference in the square root of the residual variance ; for the mean of $n$ treatments must be divided by $\sqrt{n}$. The mean difference between treatments can be tested for significance by consulting a probability table.

A direct test may be made for significance on the variances the " z " test. The difference between half the natural logarithms of the variances for treatment and error (residual variance) is entered in the table of " z " produced by Fisher, corresponding with the respective numbers of degrees of freedom, and the result can be said to be significant or not, without calculating a Standard Error.

## COMPARISON OF DIFFERENT LAY-OUTS.

In the statistical laboratory at Rothamsted, a test was made of the efficacy of different lay-outs, by calculating the significant differences, when a series of imaginary treasments was applied to uniformity data. Using Mercer and Hall's mangold data and, assuming five treatments having 99.0, 99.5, 100.0, 100.5, 101 as their respective mean yields, the percentage significances were calculated. The reduction of these differences, measures the usefulness of the various lay-outs in diminishing errors due to soil heterogeneity. The table is given below :—

ACCURACY OF DIFFERENT ARRANGEMENTS OF PLOTS IN SAME AREA TO COMPARE FIVE TREATMENTS.

(R. A. FISHER).

MERCER AND HALL'S MANGOLD DATA.

| | *Significant difference* % | *Value of Experiment.* |
|---|---|---|
| 8 Latin Squares of 25 plots each | 1.94 | 13 |
| | | 12 |
| | | 11 |
| | | 10 |
| 200 Plots with equalised rows and columns | 2.39 | 9 |
| | | 8 |
| 40 Blocks of five plots in random order | 2.67 | 7 |
| 200 Plots with equalised columns | 2.82 | 6 |
| 200 Plots in random order | 2.95 | 5 |
| | | 4 |
| | | 3 |
| 4 Blocks of strips in random order | 5.32 | 2 |
| 20 Strips in random order | 6.82 | 1 |
| | | 0 |

The lay-outs are arranged in order of value from 0 to 13 and the diminution of error due to replication and randomization is apparent. The validity of the estimate is of course dependent on whether the lay-out is random or not.

## OBSERVATION AND SAMPLING.

The above discussion concerns the range of manurial, cultivation and varietal trials where yield is the primary factor. It is however often more important to collect data of some other characteristic of the plant. The developmental history of cereals, where tillering has a big effect on yield, or where malting quality in barley, or strength in wheat are being tested, is even more important than that of yield. Disease resistance is another field where observation is of primary importance. In this type of investigation, where measurements are required on the growing crop, the amount of labour necessary, and the mass of figures produced, rules out observations over the whole plot used as the unit for yield. True observation, leading to an expression of opinion of an expert, is extremely useful, but impossible, save for a few exceptional observers. An ordinary investigator requires a more fool-proof method, and resorts to sampling. Engledow, in his cereal work, has developed a Census method for various measurements on cereals—such as tiller counts. He uses the foot length of drill as a unit, and the samples are distributed systematically over the plot. Various random methods are being tried out at Rothamsted, and in Egypt Bailey and Trought have investigated the possibility of using Selected Average Plants. More work is required along these three lines, and especially do we need a uniformity trial of some small plant, as a cereal, where the recording unit is very small, such as a foot length. The work of recording would be tremendous, but it would give data, on which tests of all sampling methods could be tried out. Furthermore, a far more detailed analysis of soil heterogeneity, than is at present possible could be made.

## PERMANENT CROPS.

Permanent crop experiments have not been included above. While the technique for annual crop trials is now on a rigid scientific basis, very little is known of the requirements with permanent crops. It is clear, however, that with planted areas produced from seedlings, the heterogeneity of the material is so great as to obscure any difference due to treatment, whatever the system of plot lay-out. The solution is obviously to produce a more even material, and to do this it is not sufficient to bud or graft stocks raised from seed. Recent work on the relation of stock on scion proves this, both in tropical crops in Sumatra and in temperate crops at East Malling Fruit Research Station in Kent.

With permanent crops moreover, we are dealing with long range experiments and it is probable that the best results will be obtained by fitting regression lines to paired observations over a number of years. An example of this is given by Nicholas in a study of mulching on cacao yields in the Gold Coast, in the 1928 Year Book of the Department of Agriculture.

## LOCAL CONTROL.

In variety trials, where one plot grows a tall plant, beside a dwarf plant, the competition is such that comparative yields are affected. This edge effect, also felt in manurial trials due to spreading, is obviated by excluding at harvest a border all round the plot, and taking the yield only of the centre portion.

## APPLICATION TO LOCAL CONDITIONS.

Where labour is wholly by hand, no restriction such as is Beaven's half-drill strips method applies. Neither are we primarily interested in having an experiment which is a good demonstration for visitors, an argument generally used in favour of strips. In the Gold Coast we can use Latin Squares and Randomised blocks as easily as any other lay-out, and as in these arrangements, the estimate of error is valid, their use is advocated. At a Conference at Asuansi Experimental Station, the system used in reorganisation of the Experimental lay-outs by the Officer-in-Charge, was considered suitable to Gold Coast conditions.

The annual crop unit is 1/40th of an acre, 33 x 33 feet square. The plots are demarcated by small concrete posts, numbered on a system, and the history of plot rendered easy to record. For permanent crops, wherever possible individual tree recording is used. The remaining areas are divided into blocks, varying in shape according to planting distances and previous lay-outs, of roughly ¼ of an acre. In both annual and permanent crops the boundary of a plot is always a crop boundary. No plot touches a road, a building or stream. The system of numbering in permanent crops is a division system whereby any individual tree is fixed by a 4-unit formula. Future policy in permanent crops should aim at producing a uniform material along the lines mentiond above.

Rotation trials are necessary, the continuous method being the most useful. If, say, three four-course rotations are to be tested 12 plots are necessary in a block. Each rotation is started at each stage in its cycle. This gives data for testing weather effects and the results are cumulative. A significant result is obtained by this method, in a shorter time than by any other. Exhaustibility trials are useful in giving suggestions for rotations, but the rotation itself must finally be tested out.

A common form of experiment is one in which two distinct treatments are tested, such as spacing and time of sowing. Here it is useful to randomise the spacing one way and the time of sowing at right angles. By doing this the sowing, recording, and harvesting are simplified.

As yet we know little of the degree of soil heterogeneity in the Gold Coast except that it is unusually high, compared with home standards. Uniformity plot trials are not necessary as a basis, where the experimental lay-outs are random, but the study is an important one, and would give useful information concerning the contributions of soil conditions and varietal differences affecting the yields in permanent crops.

## BIBLIOGRAPHY OF LITERATURE.


1908 (*a*) Wheeler, H. J.—Some desirable precautions in Plant Experimentation. Proc. Amer. Soc. Agron., Vol. 1 (1909).

(*b*) Thorne, C. E.—The Interpretation of Field Experiments. Proc. Amer. Soc. Agron., Vol. 1 (1909).

(*c*) Taylor, F. W.—The Size of Experimental Plots for Field Crops. Proc. Amer. Soc. Agron., Vol. 1 (1909).

(*d*) Morgan, J. O.—Some Experiments to Determine the Uniformity of certain Plats for Field Tests. Proc. Amer. Soc. Agron., Vol 1.

(*e*) Student.—The Probable Error of a Mean. Biometrika, Vol. VI, 1908.

1909 (*a*) Hall, A. D.—The Experimental Error of Field Trials. Jorn. Bd. Agric. (Great Britain), Vol. 16.

1910 (*a*) Wood, T. B.—The Feeding Value of Mangels. Jorn. Agric. Sci., Vol. 3, No. 3.

(*b*) Wood, T. B. and Stratton, F. J. M.—The Interpretation of Experimental Results. Jorn. Agric. Sci., Vol. 3, No. 4.

(*c*) Montgomery, E. G.—Methods for Testing the Seed Value of Light and Heavy Kernels in Cereals. Proc. Amer. Soc. Agron., Vol. 2.

(*d*) Piper, C. V. and Stevenson, W. H.—Standardisation of Field Experimental Methods in Agronomy. Proc. Amer. Soc. Agron., Vol. 2.

(*e*) Lyon, T. L.—Comparison of the Error in Yields of Wheat. Proc. Amer. Soc. Agron., Vol. 2.

1911 (*a*) Dobbs, A. C.—Field Experiments. Agric. Journ. of India, Vol. 6 Pt. 1.

(*b*) Hall, A. D. Russell, E. J., Wood, T. B., etc.—The Interpretation of the Results of Agricultural Experiments. Supplement No. 7. Jorn. Bd. Agric. (Great Britain), Nov. 1911.

(*c*) Mercer, W. and Hall, A. D. (Appendix by Student).—Experimental Error of Field Trials. Jorn. Agric. Sci., Vol. 4, No. 2.

(*d*) Lyon, T. L.—Some Experiments to Estimate Errors in Field Plat Tests. Proc. Amer. Soc. Agron., Vol. 3.

1913 (*a*) Salmon, C.—A Practical Method of Reducing Experimental Error in Varietal Tests. Journ. Amer. Soc. Agron., Vol. 5, pp. 182—18.

(*b*) Coffey, G. N.—The Purpose and Interpretation of Fertilizer Experiments. Jorn. Amer. Soc. Agron., Vol. 5, No. 4.

1914 (*a*) Collins, G. N.—A more accurate Method of Comparing First Generation Maize Hybrids with their Parents. Jorn. Agric. Res., Vol. 3, No. 1, pp. 85–91.

(*b*) Wiancko, A. T.—Use and Management of Check Plats in Soil Fertility Investigations. Jorn. Amer. Soc. Agron., Vol. 6, pp. 122–124.

(*c*) Salmon, C.—Check Plats—A Source of Error in Varietal Tests. Jorn. Amer. Soc. Agron., Vol. 6, pp. 128–130.

(*d*) Barber, C. W.—Note on the Influence of Shape and Size of Plots in Tests of Varieties of Grain. Maine Agric. Expt. Sta. Bull. 226.

(*e*) Surface, F. M. and Barber, C. W.—Studies in Oat Breeding. Maine Agric. Expt. Sta. Bull. 229.

(*f*) Olmstead, L. B.—Some Applications of the Method of Least Squares to Agricultural Experiments. Jorn. Amer. Soc. Agron., Vol. 6 p. 190.

(*g*) Pearl, R. and Miner, J. R.—A Table for estimating the Probable Significance of Statistical Constants. Maine Agric. Expt. Sta., 30th Ann. Rep. 1914.

1915 (*a*) Harris, J. A.—On a Criterion of Substratum Momogeneity or Heterogeneity in Field Experiments. Amer. Nat. Vol. 49, No. 583.

(*b*) Balls, W. L.—Analysis of Agricultural Yields, Pt. III. Proc. Roy. Soc., Series B., Vol. 208.

(*c*) Annet, H. E.—The Experimental Error in Field Trials with Sugarcane and the Effect on this Error of Various Methods of Sampling. Agric. Res. Inst., Pusa, Bull 49.

1916 (*a*) Surface, F. M. and Pearl, R.—A Method of correcting for Soil Heterogeneity in Variety Tests. Journ. Agric. Res., Vol. 5, No. 22.

(*b*) Pritchard, F. J.—The Use of Checks and Plantings in Varietal Tests. Jorn. Amer. Soc. Agron., Vol. 8, No. 2.

(*c*) Stockberger, W. W.—Relative Precision of Formulae of. Calculating Normal Plot Yields. Journ. Amer. Socr Agron., Vol. 8, No. 2.

(*d*) Coombs, G. E. and Grantham, J.—Field Experiments and the Interpretation of their Results. Agric. Bull. Fed. Malay States, Vol. 4, No. 7.

1917 (*a*) Hayes, H. K. and Arny, A. C.—Experiments in Field Technic in Rod Row Tests. Journ. Agric. Res., Vol. 11, p. 399.

1918 (*a*) Kiesselbach, T. A.—Studies concerning the Elimination of Experimental Error in Comparative Crop Tests. Nebraska Expt. Sta. Research Bull., No. 13.

(*b*) Batchelor, D. and Reed, H. S.—Relation of the Variability of Yields of Fruit trees to the Accuracy of Field Trials. Jorn. Agric. Res., Vol. 12, No. 2.

(*c*) Arny, A. C. and Hayes, H. K.—Experiments in Field Technic in Plot Tests. Jorn. Agric. Res., Vol. 15, pp. 251–262.

1919 (*a*) Arny, A. C. and Garber, R. J.—Field Technic in determining Yields of Plots of Grain by the Rod Row Method. Jorn. Amer. Soc. Agron., Vol. 11, No. 1.

(*b*) Arny, A. C. and Steinmetz, F. H.—Field Technic in determining Yields of Experimental Plots by the Square Yard Method. Journ. Amer. Soc. Agron., Vol. 11, No. 3.

(*c*) Kiesselbach, T. A.—Plat Competition as a Source of Error in Crop Tests. Journ. Amer. Soc. Agron., Vol. 11.

(*d*) Kiesselbach, T. A.—Experimental Error in Field Trials. Journ. Amer. Soc. Agron., Vol. 11, No. 6.

(*e*) Parnell, F. R.—Experimental Error in Variety Test with Rice. Agric. Journ. India, Vol. 14, Pt. 5.

(*f*) Love, H. H.—The Experimental Error in Field Trials. Journ. Amer. Soc. Agron., Vol. 11.

1920 (*a*) Day, J. W.—The Relation of Size, Shape, and Number of Replications of Plats to probable Error in Field Experimentation. Journ. Amer. Soc. Agron., Vol. 12, No. 3.

(*b*) Harris, J. A.—Practical Universality of Field Heterogeneity as a Factor influencing Plot Yields. Journ. Agric. Res., Vol. 19, p. 279.

(*c*) Harris, J. A. and Scofield, C. S.—Permanence of Differences in the Plots of an Experimental Field. Journ. Agric. Res., Vol. 20, No. 5.

(*d*) Harris, F. S. and Butt, N. J.—The Unreliability of Short Time Experiments. Journ. Amer. Soc. Agron., Vol. 12, No. 5.

(*e*) Spragg, F. A.—The Coefficient of Yield. Journ. Amer. Soc. Agron., Vol. 12, No. 5.

1921 (*a*) Fisher, R. A.—Studies in Crop Variation. J. Agric. Sci. II, 107–135.

(*b*) Arny, A. C.—Further Experiments in Field Technic in Plot Tests. Journ. Agric. Res., Vol. 21, p.483.

1922 (*a*) Beaven, E. S.—Trials of New Varieties of Cereals Journ. Min. Agric. (London), Vol. 29, Nos. 4 and 5.

(*b*) Beaven, E. S.—Supplement to 1922 (*a*).

(*c*) Arny, A. C.—Border Effects and Ways of avoiding it. Journ. Min. Soc. Agron., Vol. 14, No. 7.

1923 (*a*) Engledow, F. L. and Wadham, S. M.—Analysis of Yield in Cereals. Journ. Agric. Sci., Vol. XIII, Pt. IV and Vol. XIV, Pts. I, II, and III.

(*b*) Faulkner, O. T.—Unavoidable Error of Field Experiments. Agric. Journ. India, Vol. 18, Pt. 3.

(*c*) Student.—On Testing Varieties of Cereals. Biometrika, Vol. 15, Pts. 3 and 4.

(*d*) Anon.—The Estimate of Probabilities applied to Field Experiments. Internat. Rev. Sci. and Prac. Agric. New Series, Vol. 1, No. 4.

(*e*) Love, H. H.—The Importance of the Probable Error Concept in the Interpretation of Experimental Results. Journ. Amer. Soc. Agron., Vol. 15, No. 6.

(*f*) Hayes, H. K.—Controlling Experimental Error in Nursery Trials. Journ. Amer. Soc. Agron., Vol. 15, No. 5.

(*g*) Faulkner, O. T.—A Note on the Interpretation of Field Trials. Nigeria Agric. Bulletin, July, 1923.

(*h*) Summerby, R.—Replication in Relation to Accuracy in Comparative Crop Tests. Journ. Amer. Soc. Agron., Vol. 15, No. 5.

(*i*) Kiesselbach, T. A.—Competition as a Source of Error in Comparative Corn Yields. Journ. Amer. Soc. Agron., Vol. 15, No. 5.

(*j*) Salmon, S. C.—Some Limitations in the Application of the Method of Least Squares to Field Experiments. Journ. Amer. Soc. Agron., Vol. 15, No. 6.

1924 (*a*) Wiancko, A. T. et alia—Report of the Committee on Standardization of Field Experiments. Journ. Amer. Soc. Agron., Vol. 16, No. 1.

(*b*) Richey, F. D.—Adjusting Yields to their Regression on a moving Average, as a means of Correcting for Soil Heterogeneity. Journ. Agric. Res., Vol. 27, No. 2.

(*c*) Love, H. H.—Student's Method for Interpreting paired Experiments. Journ. Amer. Soc. Agron., Vol. 16, No. 1.

(*d*) Love, H. H.—A Modification of Student's Table for use in Interpreting Experimental Results. Journ. Amer. Soc. Agron., Vol. 16, No. 1.

1924 (*a*) The Techinque of Plot Arrangement. Imp. Bot. Conference Report.—E. J. Maskell.

1925 (*a*) Trought, T.—A Statistical Note on the Cotton Variety Tests at Sakha 1916–1920. Ministry of Agriculture, Egypt, Tech. Bull. No. 51.

(*b*) Engledow, F. L.—Investigations on Yield in the Cereals II. J. Agr. Sci. 15.

1926 (*a*) Fisher, R. A.—The Arrangement of Field Experiment. Jl. Min. Agric. 33, 505–513.

(*b*) Lord, L.—The preliminary testing of pure line selections of rice. Trop. Agriculturist 67, 272–385.

(*c*) Russell, J.—Field Expts. how they are made and what they are. J. Min. Agric. 32, 989–1001.

(*d*) Engledow & Yule.—The Principles and Practice of Yield Trials. Empire Cotton Growing Corporation 27s.

(*e*) Bailey & Trought.—Experimental Error of Field Trials with cotton in Egypt. Min. of Agric. Egypt, Bull. No. 63.

(*f*) Student.—Mathematics and Agronomy. J. Amer. Soc. Agron., 18, 8.

(*g*) Parish, E.—Agric. Experiment. Its Design and Interpretation. Bull. No. 22, Dept. of Agric. Preporia, S.A.

(*h*) Engledow, F. L.—A Census of an acre of corn. J. Agric. Sci., 16

1927 (*a*) Eden & Fisher.—Studies in Crop Variation IV. J. Agric. Sci., XVII, IV.

1928 (*b*) Doughty & Engledow—Investigations on yield in the Cereals V. J. Agric. Sci., 18, II.

(*c*) Steven—Nursery Investigations. Forestry Commission Bulletin, No. 11.

(*d*) Iliffe & Nath—The Conduct of Field Experiments. Bull. No. 89, Dept. of Agric. Madras.

1929 (*a*) Maskell, E. J.—Experimental Error. Trop. Agriculture V, 12.

(*b*) Hines & Wishart (Rothamstead)—Replicated Expts. on the ordinary Farm (in preparation).

## REFERENCE BOOKS.

Undy Yule—Introduction to the Theory of Statistics.

R. A. Fisher—Statistical Methods for Research Workers.

P. MacMahon—Combinatory Analysis, Vol. I (Chapter on Latin Square Theory).

W. N. Feldman—Biomathematics.

Whittaker & Robinson—Calculus of Observations.

## PAPER No. XXXVIII.

# CHLORINE CONTENT OF CERTAIN WELLS IN KETA DISTRICT.

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(*The analyses and general supervision of the work dealt with in this paper were carried out by Mr. R. W. Clarke, F.I.C., Analytical Chemist to the Medical Department and the collection of the samples and field work by Mr. J. O. Torto of the Department of Agriculture*).

At the instance of the Director of Agriculture an investigation has been started on the subject of the quantity and character of the mineral constituents of subsoil water in the Colony, with a view to trying to map out a " water-table," or general level at which sweet water is kept up by percolation of sea-water into the underlying portions of pervious strata. It is intended that the investigation be carried out on all existing wells along the coast, and working inland. Only a very small number of wells have been dealt with at present, but it has been suggested that a preliminary report on the results obtained from one particular group might be of interest.

This group consists of 46 wells in the neighbourhood of Keta.

Keta lies on a narrow strip of sandy soil only a few hundred yards wide, dividing the sea from a lagoon. The lagoon is intermittently connected with the sea. It is also intermittently fed by surface-water after rain. Its water level and salinity are therefore liable to considerable seasonal fluctuations. At the time the samples analysed were taken it was unusually dry. On this narrow strip of land are some 120 wells, most of them to the south of Keta. All are believed to be shallow; none of those tested exceeded 12 feet in depth. The height of the land is nowhere more than about 10 feet above sea-level. The 46 wells dealt with are all in or near the town, on a line measuring some $3\frac{1}{2}$ miles. In the table of results they are numbered roughly from north to south, though naturally some lie more or less east and west of one another. Some of the samples are derived from a number of wells in close proximity. No. 14, for example, is from 15 wells in a yard of about 40 yards square.

The samples were collected by Mr. Torto of the Agricultural Department, who also measured the depth of the wells and the water-levels. He also did a considerable amount of the chemical work.

Chlorides were determined (volumetrically) in all samples. Those in which this figure indicated that there was infiltration of sea-water to a considerable extent were not further investigated. Of the remainder, a selection was made, comprising practically all those of low chlorine-content, and some of those giving medium and high figures (up to 96 parts per 100,000). The total solids and temporary and permanent hardness of these were determined (volumetrically with acid and alkali). No investigation into organic purity was carried out, because it was obvious that all were liable to pollution: in fact many are mere sumps into which the surface-water in the immediate neighbourhood drains. The water appears to be used solely for agricultural purposes. Moreover, the degree of pollution must vary from day to day. Some of the wells are cemented inside. Others are merely barrels with the ends knocked out, sunk in the ground.

It is interesting to note that in spite of their shallowness and limited catchment-area, according to the information that Mr. Torto was able to elicit from the owners, none of them ever runs dry, even in the harmattan season.

The samples were collected in October 1928 as follows:—Nos. 1–4 on 11th, 5–16 on 12th, 17–23 on 13th, 24–29 on 14th, 30–41 on 15th, 42–44 on 16th, and 45 and 46 on 17th. The recent rainfall was as follows:—from 1st to 8th October 3.43 inches, on 12th, 0.57 inch, on 13th, 0.56 inch, and on 16th, 0.80 inch.

The data are tabulated below. The analytical data are expressed in parts per 100,000, the depths in feet; and the letters B and C indicate that the lining of the well consisted of barrels or cement respectively.

| Serial Number. | Lined. | Depth of well. | Depth to water. | Chlorine. | Total solids. | Temp. hardness. | Perim. hardness. |
|---|---|---|---|---|---|---|---|
| 1 | C | 7 | 5 | 1020 | | | |
| 2 | C | 10 | 7 | 170.0 | | | |
| 3 | B | 9 | 7 | 103.0 | | | |
| 4 | B | 8 | 6 | 43.5 | 115.0 | 17.4 | 21.0 |
| 5 | C | 10 | 7 | 175.0 | | | |
| 6 | C | 7 | 5½ | 180.0 | | | |
| 7 | C | 10 | 7 | 152.0 | | | |
| 8 | C | 10 | 6 | 1645.0 | | | |
| 9 | C | 11 | 7 | 250.0 | | | |
| 10 | C | 6 | 4¾ | 495.0 | | | |
| 11 | C | 11 | 9 | 470.0 | | | |
| 12 | C | 12 | 9 | 245.0 | | | |
| 13 | B | 9 | 7 | 180.0 | | | |
| 14 | B | 4½ | 2½ | 26.0 | 103.0 | 28.2 | 11.4 |
| 15 | C | 9 | 6 | 225.0 | | | |
| 16 | B | 6 | 5 | 625.0 | | | |
| 17 | C | 7 | 4½ | 290.0 | | | |
| 18 | B | 7½ | 4½ | 155.0 | | | |
| 19 | C | 7 | 5 | 210.0 | | | |
| 20 | C | 8 | 6 | 190.0 | | | |

| Serial Number. | Lined. | Depth of well. | Depth to water. | Chlorine. | Total Solids. | Temp. hardness. | Perim. hardness. |
|---|---|---|---|---|---|---|---|
| 21 | B | 6 | 4 | 120.0 | | | |
| 22 | B | 6 | 4 | 240.0 | | | |
| 23 | B | 5½ | 4 | 215.0 | | | |
| 24 | B | 6 | 4½ | 290.0 | | | |
| 25 | B | 6½ | 5 | 360.0 | | | |
| 26 | C | 7 | 5½ | 545.0 | | | |
| 27 | C | 7½ | 5 | 310.0 | | | |
| 28 | B | 6 | 4½ | 96.0 | | | |
| 29 | B | 6 | 5 | 300.0 | | | |
| 30 | B | 6½ | 5 | 560.0 | | | |
| 31 | C | 9 | 7 | 1145.0 | | | |
| 32 | B | 7 | 6½ | 825.0 | | | |
| 33 | C | 8 | 6 | 96.0 | 322.0 | 19.5 | 42.6 |
| 34 | B | 6 | 4½ | 62.0 | | | |
| 35 | C | 9 | 6 | 205.0 | | | |
| 36 | B | 10 | 8 | 25.0 | 79.0 | 24.1 | 7.8 |
| 37 | C | 12 | 9 | 11.5 | 53.0 | 21.5 | 0.5 |
| 38 | C | 9 | 7 | 1.7 | 21.0 | 13.8 | 1.5 |
| 39 | B | 8 | 7 | 13.0 | 76.0 | 32.8 | 6.8 |
| 40 | B | 8 | 6 | 9.3 | 58.0 | 19.9 | nil |
| 41 | B | 6 | 4½ | 11.3 | 55.0 | 31.1 | 0.5 |
| 42 | C | 9 | 6 | 37.5 | 158.0 | 32.3 | 8.8 |
| 43 | C | 9 | 6 | 5.4 | | | |
| 44 | C | 9 | 6 | 1.7 | 33.0 | 21.3 | nil |
| 45 | C | 12 | 5½ | 605.0 | | | |
| 46 | C | 10 | 8 | 320.0 | | | |

## PAPER No. XXXIX.

# THE HARMATTAN AND ATMOSPHERIC HUMIDITY.

By N. P. CHAMNEY.

The origin and phenomena of the Harmattan season have been dealt with in Bulletin No. 15 of this Department and this paper is only concerned with the influence which the dry North-east wind, which prevails during this period, has on the atmospheric moisture. This influence is one of extreme desiccation and is the most characteristic phenomenon of the Harmattan.

## THE WATER CONTENT OF AIR.

The amount of water necessary to saturate a given volume of air at a given temperature is known (Table I) and this varies for every degree of temperature. When the temperature of the air is raised, it is capable of holding a greater quantity of water vapour before the point of saturation is reached and conversely when the temperature is lowered the moisture holding capacity of the same volume of air is lessened.

Roughly speaking for every 20°F variation in the temperature the weight of water necessary to saturate a given volume of air is doubled or halved according to whether the temperature rises or falls.

## RELATIVE HUMIDITY.

The atmosphere is rarely at saturation point for any length of time and the amount of water actually present in the air is not constant.

In order to express the hygrometric state of the atmosphere for purposes of comparison it is necessary to take into consideration two factors.

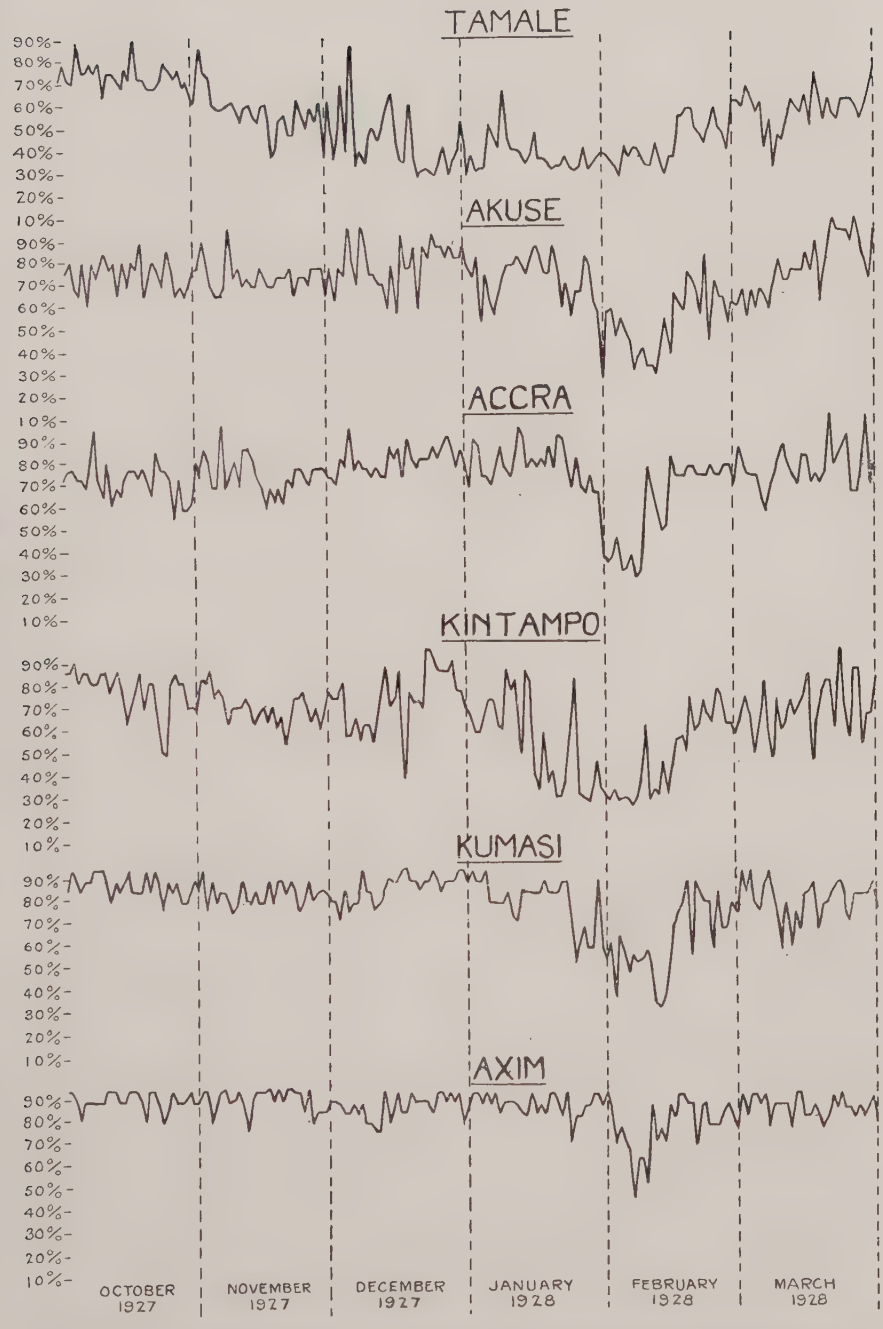
(*a*) The quantity of water vapour necessary to saturate the air at the temperature of that air.

(*b*) The amount of water actually present in the air at the moment of observation.

The ratio of (*b*) to (*a*) is expressed as percentage and is known as the relative humidity.

When the water vapour in the air at any time is one half as much as it is possible for the air to hold at that temperature, the relative humidity is said to be 50%.

PLATE LXVII.




DEPRESSIONS OF ATMOSPHERIC RELATIVE HUMIDITY DURING THE HARMATTAN.

A room 20′ x 20′ x 10′ contains 4,000 cubic feet of air and at 80° if completely saturated would contain six pints of water in the form of vapour. If however the Relative Humidity was 80%, as recorded by the wet and dry bulb hygrometer, the actual water content of that volume of air would be just under five pints.

During the day the amount of moisture in the air is seldom sufficient for saturation but when the temperature falls in the evening the moisture holding capacity of the air falls and the Relative Humidity rises. If it rises to saturation point (100%) dew is formed and the temperature at which this occurs is known as the dew-point.

## INFLUENCE OF THE HARMATTAN.

When dry air passes over a free water surface, it tends, in obedience to physical laws, to take up water in order to become in equilibrium with the surface over which it is passing. The rate of absorption of this water, as vapour, depends on the temperature, wind velocity, dryness of the air, and to some extent the pressure of the atmosphere.

During the Harmattan the air is very dry due to the fact that the wind blows direct from the central deserts of Africa and has not encountered any large free water surface in its path. The temperature is high and the velocity of the wind about 8–10 miles per hour. These factors are favourable to rapid desiccation and in consequence any objects which will yield moisture to the air such as the foliage of plants, the skin of human beings and even such things as furniture, books, etc. which have been hitherto in a moist climate are dried out.

The "pull" exerted by any force desiring to become in equilibrium with another is greatest at the commencement and becomes relatively less as it approaches equilibrium and therefore the "pull" of the dry air on moisture-holding objects may be guaged by the fact that the relative humidity may drop from 80% to 20% sometimes in 24 hours at the incidence of the Harmattan. It is plain that the desiccating power of the Harmattan will be greater when the relative humidity falls to 20% than at 50%.

## VARIATION IN DESICCATION.

By graphing the 9 a.m. readings of the relative humidity as recorded by the hygrometer a very good idea of the intensity of the Harmattan is obtained. This has been done for all stations in 1928 and the results are shown in Plates LXVII and LXVIII.

From a study of these graphs it will be seen that the greatest intensity is experienced in the North and South-east but that the duration is longest in the North. Tamale experiences a very long intense Harmattan while the more southerly stations such as Kintampo, Kumasi, Kpeve, Akuse, Aburi and Accra record also low relative humidity but for shorter periods.

Axim, Asuansi and Tarkwa have large areas of forest between them and the origin of the dry wind and therefore experience much less intensity of desiccation and for a very short period. This is due to the absorption of water by the North-east wind when passing over the moist forest area and in consequence exerting less "pull" owing to greater percentage saturation.

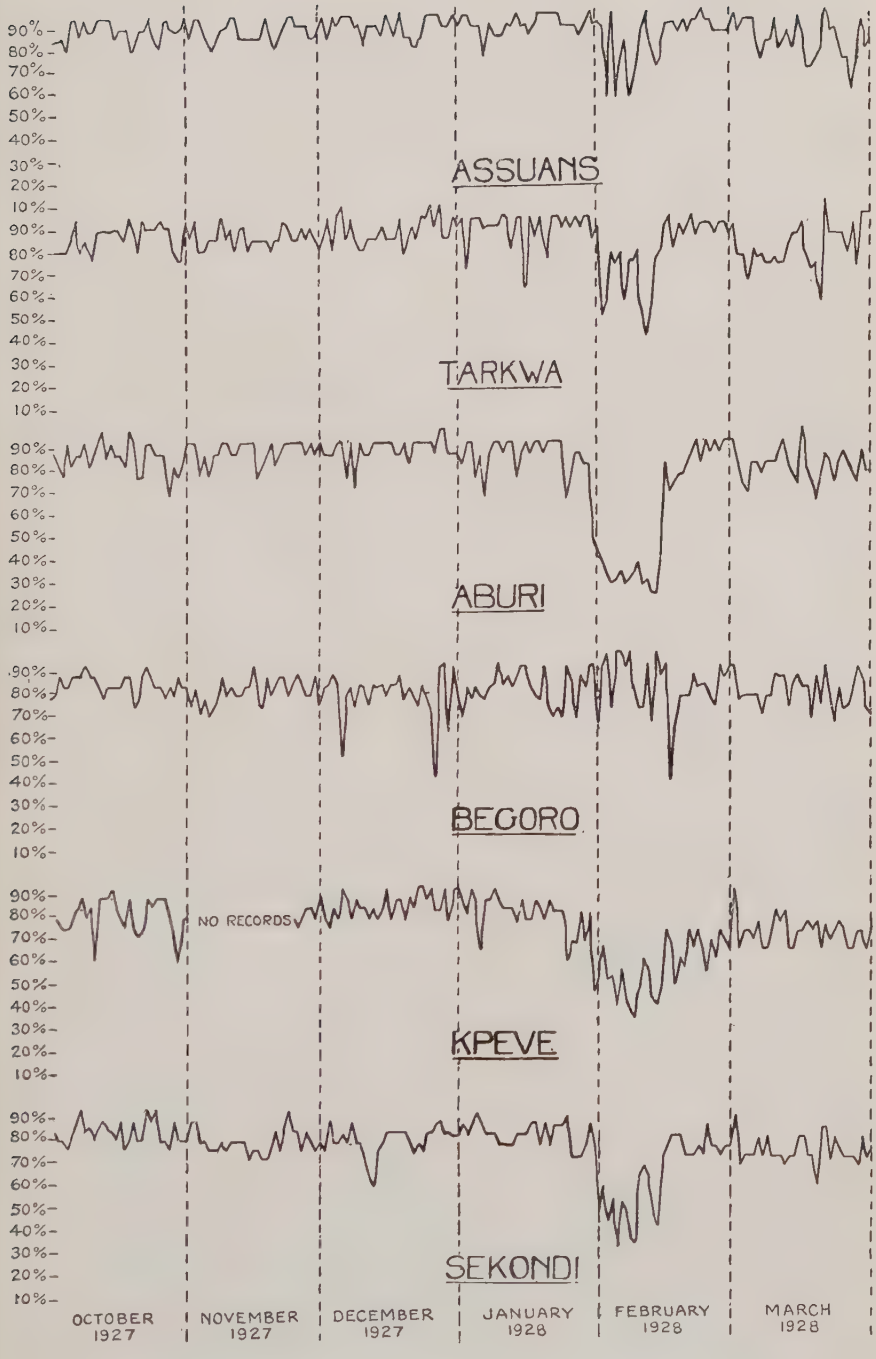
The greatest desiccation during a day is experienced about 2 p.m. due probably to the assistance in evaporation given by the heat of the sun's rays and also to the greater moisture holding capacity of the air a higher temperature reducing the relative humidity.

## TABLE I.

### Mass of water in grams per cubic metre at varying Dew Point.

| Temperature °F | Mass of water in grams at saturation point. | Temperature °F. | Mass of water in grams at saturation point. | Temperature °F. | Mass of water in grams at saturation point. |
|---|---|---|---|---|---|
| 33.8 | 5.2 | 51.8 | 10.0 | 69.8 | 18.2 |
| 35.6 | 5.6 | 53.6 | 10.6 | 71.6 | 19.3 |
| 37.4 | 6.0 | 55.4 | 11.3 | 73.4 | 20.4 |
| 39.2 | 6.4 | 57.2 | 12.0 | 75.2 | 21.5 |
| 41.0 | 6.8 | 59.0 | 12.8 | 77.0 | 22.9 |
| 42.8 | 7.3 | 60.8 | 13.6 | 78.8 | 24.2 |
| 44.6 | 7.7 | 62.6 | 14.5 | 80.6 | 25.6 |
| 46.4 | 8.1 | 64.4 | 15.1 | 82.4 | 27.0 |
| 48.2 | 8.8 | 66.2 | 16.2 | 84.2 | 28.6 |
| 50.0 | 9.4 | 68.0 | 17.2 | 86.0 | 30.1 |

PLATE LXVIII.




DEPRESSIONS OF ATMOSPHERIC RELATIVE HUMIDITY DURING THE HARMATTAN.

PAPER No. XL.

# METEOROLOGICAL RECORDS OF THE GOLD COAST FOR 1928.

Compiled by N. P. Chamney and J. M. Adams.

The whole of the meteorological data available up to the end of 1927 have been summarized and published with explanatory notes as Bulletin No. 15 of this Department. Special appendices on the Harmattan and a phenomenon known as the "tiring of thermometers" were also included.

This paper deals only with the actual records of the past year which has been a somewhat exceptional one in certain respects.

The Harmattan was late, only commencing at the majority of the stations late in January and the 1929 Harmattan had already commenced in November and December 1928 which is exceptionally early.

The rainfall on the majority of the stations was heavier than in the preceding year and in Accra the temperature during July, August and September was much lower than the normal.

**Stations.**

Of the meteorological stations, Tarkwa has been closed owing to the closing down of the Agricultural Station, while a new station has been opened at Atwabo and that at Cape Coast has been re-opened. In addition records are now available for a complete year from Kpeve and Achimota.

New Rainfall stations have been opened at Akropong (Ashanti) Akpafu, Amedjofe, Dafo, Kajebi, Djoje, Honuta, Mpayo, Kpandu (all in Togoland) Otrokpe and Bunso (Eastern Province) and Winneba and Cape Coast in the Central Province. Adeja and Asumenya (in Ashanti), Wioso (W. Province), Hemang (Central Province) and Peki Blengo (Eastern Province), have been closed due, in the last three cases, to the closing down of the Agricultural Stations at these places.

**Rainfall Tables.**

The monthly distribution of rainfall during 1928 is given for all stations in Table II together with the highest and lowest annual figures. Unusual figures are recorded at Atwabo 105.72 inches in 154 days and Labadi 18.65 inches in 53 days. The monthly figures which are notable are Atwabo 35.02 inches in June, Mpennasa 34.94, Butre 30.37 also in June. The greatest rainfall recorded in any one day was 6.07 inches at Axim on May 28.

The Rainfall Map as in previous years is based on the average rainfall of each station up to and including 1928 but the records from the new stations where a complete year's rainfall has not been recorded will not be included until 1929. Most of these new stations have been opened with the idea of obtaining information as to the relation of the rainfall of the Gold Coast to that of the neighbouring country of Togoland (French Mandated Sphere). It is hoped to be able to establish stations during 1929 to obtain similar information with regard to the Ivory Coast.

The Degrees of wetness of stations are given in Table I and are obtained by multiplying the rainfall in inches by the number of wet days and dividing by 100. The graph arrived at by plotting the position of stations with regard to rainfall and number of wet days (Bulletin No. 15 opposite p. 10) shows how the relation of total fall to number of wet days divides the stations into definite zones.

**Temperatures.**

The average monthly figures for the maximum, minimum and mean temperatures in the shade for all stations is given in Table III.

The highest temperature in the shade recorded during the year was 107° at Tamale on March 10th and the lowest 50° at Kumasi on December 30th and Kintampo on 7th, 11th, 12th and 13th of February.

The highest sun temperature was 177° at Tamale on March 20th.

**Relative Humidity.**

The monthly distribution of Relative Humidity is given for all stations in Table IV. The variation in this figure due to the desiccating effect of the Harmattan is well shown by the plates included in the previous paper (Paper No. 39.)

**Climatic Charts.**

During 1928 a daily chart showing the relation of all readings has been prepared for Accra station and other charts showing similar records for other stations will be prepared shortly. From a study of these and other observations it is hoped that a system of forecasting weather may eventually be arrived at which will be of use to farmers in dealing with their crops and also engineers, shippers and other members of the community whose occupation needs some warning as to the possibility of a change in weather conditions.

# TABLE I.

## Degrees of Wetness—1928.

| | |
|---|---|
| Atwabo | 163 |
| Abomposo | 117 |
| Dadiasu | 116 |
| Kintampo | 105 |
| Dentin, Tarkwa | 104 |
| Kibi | 90 |
| Seysie (Butre) | 87 |
| Juaso | 85 |
| Half-Assini, Nkawkaw | 82 |
| Oda | 80 |
| Kete Kratchi | 79 |
| Imprim | 77 |
| Kumasi | 76 |
| Agona | 74 |
| Mpraeso | 73 |
| Otikrom | 72 |
| Effiduasi | 71 |
| Asamankese, Axim, Ejisu | 70 |
| Essuaso, Bekwai, Mampong (Ashanti) | 69 |
| Dunkwa, Kpeve | 68 |
| Begoro | 66 |
| Akropong (Ashanti) | 65 |
| Asuansi, Mpennasa | 64 |
| Kodia Kese | 63 |
| Koforidua, Ho | 61 |
| Bunso, Manso | 60 |
| Ejura, Goaso | 58 |
| Asromaso | 57 |
| Sekondi, Wa | 56 |
| Aburi | 53 |
| Bole, Dafo | 52 |
| Tafo | 49 |
| Salaga, Wenchi, Akpafu | 48 |
| Sunyani, Angu | 47 |
| Akropong (Akwapim), Lawra | 41 |
| Kajebi | 40 |
| Ajua, Navrongo, Tamale | 34 |
| Abra, Yendi | 33 |
| Gambaga | 30 |
| Otrokpe | 29 |
| Cape Coast | 28 |
| Akuse, Odumase | 27 |
| Bawku | 26 |
| Mpayo, Zuarungu, Nsawam | 25 |
| Saltpond | 23 |
| Accra | 17 |
| Achimota | 14 |
| Keta | 13 |
| Labadi | 10 |

# TABLE II.

## Summary of Rainfall in inches for all Stations in the Gold Coast for the Year 1928.

| Month. | 1 Atwabo (2 years). | 2 Siwum (Dadiasu) (7 years). | 3 Dentin (2 years). | 4 Axim (14 years). | 5 Otikrom (3 years). | 6 Kintampo (14 years). | 7 Half-Assini (7 years). | 8 Mpennasa (4 years). | 9 Seysie (Butre) (8 years). | 10 Abompaso (16 years). | 11 Essuaso (3 years). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January .. .. .. .. .. | 4.01 | 0.90 | 0.80 | 1.65 | 0.32 | 0.21 | 0.75 | 0.36 | 0.00 | 0.33 | 0.00 |
| February .. .. .. .. .. | 0.06 | 0.65 | 1.00 | 0.95 | 2.51 | 0.12 | 0.55 | 0.56 | 0.58 | 0.01 | 2.92 |
| March .. .. .. .. .. | 1.75 | 9.59 | 5.10 | 4.09 | 9.41 | 8.20 | 2.60 | 4.03 | 3.03 | 6.69 | 3.08 |
| April .. .. .. .. .. | 10.89 | 5.51 | 8.10 | 4.44 | 8.42 | 11.07 | 8.98 | 4.27 | 3.68 | 4.62 | 3.86 |
| May .. .. .. .. .. .. | 16.43 | 11.02 | 10.28 | 23.57 | 7.93 | 10.56 | 8.86 | 14.11 | 21.66 | 11.32 | 8.80 |
| June .. .. .. .. .. .. | 35.02 | 15.49 | 12.17 | 26.22 | 8.06 | 7.54 | 28.80 | 34.94 | 30.37 | 11.43 | 21.65 |
| July .. .. .. .. .. .. | 3.12 | 8.42 | 6.81 | 3.71 | 5.91 | 10.96 | 3.90 | 2.48 | 1.28 | 8.28 | 5.57 |
| August .. .. .. .. .. | 2.16 | 2.58 | 4.08 | 0.78 | 4.72 | 6.19 | 1.45 | 1.76 | 3.33 | 4.15 | 1.07 |
| September .. .. .. .. | 3.64 | 5.38 | 12.26 | 1.07 | 15.86 | 10.82 | 1.69 | 2.17 | 1.16 | 5.88 | 4.16 |
| October .. .. .. .. .. | 6.45 | 14.45 | 16.74 | 4.75 | 11.77 | 9.96 | 7.49 | 7.08 | 5.42 | 16.12 | 10.79 |
| November .. .. .. .. .. | 9.58 | 5.08 | 4.22 | 3.86 | 2.09 | 1.37 | 6.31 | 1.23 | 1.87 | 4.33 | 6.82 |
| December .. .. .. .. .. | 2.61 | 4.01 | 0.66 | 4.80 | 0.72 | 0.00 | 5.15 | 2.73 | 3.39 | 1.52 | 1.94 |
| Total .. .. .. .. | 105.72 | 83.08 | 82.22 | 79.89 | 77.72 | 77.00 | 76.53 | 75.72 | 75.47 | 74.68 | 70.66 |
| Number of Rainy Days (.01 inch or more) | 154 | 140 | 127 | 87 | 92 | 138 | 107 | 84 | 115 | 157 | 99 |
| Highest previous Rainfall .. .. | 79.02 | 73.62 | 91.04 | 109.65 | 59.37 | 100.58 | 88.77 | 60.27 | 58.96 | 73.04 | 102.63 |

SUMMARY OF RAINFALL IN INCHES FOR ALL STATIONS IN THE GOLD COAST FOR THE YEAR 1928.

| MONTH. | 12 Imprim (3 years). | 13 Juaso (13 years). | 14 Kete-Kratchi (10 years). | 15 Kodia Kese (3 years). | 16 Effiduasie (2 years). | 17 Tarkwa (25 years). | 18 Nkawkaw (3 years). | 19 Begoro (7 years). | 20 Ejisu (3 years). | 21 Mpraeso (11 years). | 22 Ejura (13 years). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January .. .. .. .. .. | 0.42 | 0.84 | 0.30 | 0.00 | 0.34 | 1.75 | 0.35 | 0.62 | 0.71 | 0.00 | 0.19 |
| February .. .. .. .. .. | 2.30 | 0.13 | 0.62 | 0.82 | 0.77 | 2.23 | 0.00 | 2.69 | 3.38 | 0.24 | 0.00 |
| March .. .. .. .. .. | 8.92 | 7.22 | 5.76 | 7.09 | 5.61 | 2.32 | 7.83 | 9.33 | 11.32 | 6.31 | 4.06 |
| April .. .. .. .. .. | 4.54 | 5.95 | 5.70 | 10.08 | 6.82 | 5.71 | 6.35 | 8.84 | 5.82 | 5.80 | 11.89 |
| May .. .. .. .. .. .. | 8.68 | 6.13 | 9.21 | 7.55 | 9.45 | 6.66 | 5.09 | 4.97 | 9.57 | 7.31 | 9.96 |
| June .. .. .. .. .. .. | 8.71 | 9.78 | 3.20 | 9.68 | 11.00 | 18.46 | 7.71 | 6.80 | 5.45 | 9.85 | 6.50 |
| July .. .. .. .. .. .. | 4.48 | 7.30 | 7.86 | 2.17 | 2.91 | 6.40 | 6.44 | 8.70 | 2.56 | 5.27 | 1.57 |
| August .. .. .. .. .. | 4.04 | 5.10 | 4.89 | 2.36 | 1.64 | 1.78 | 3.17 | 2.90 | 2.95 | 5.35 | 3.95 |
| September .. .. .. .. | 9.69 | 12.34 | 14.49 | 12.80 | 9.37 | 2.95 | 12.54 | 6.92 | 9.90 | 11.69 | 7.11 |
| October .. .. .. .. .. | 12.47 | 6.50 | 10.64 | 11.16 | 12.84 | 8.51 | 10.98 | 9.63 | 9.79 | 7.70 | 14.42 |
| November .. .. .. .. .. | 2.81 | 2.55 | 3.67 | 2.48 | 3.57 | 5.53 | 3.06 | 1.52 | 1.73 | 1.72 | 2.96 |
| December .. .. .. .. .. | 0.53 | 2.77 | 0.25 | 0.00 | 1.70 | 2.58 | 1.23 | 1.69 | 0.73 | 1.89 | 0.16 |
| Total .. .. .. .. | 67.59 | 66.71 | 66.59 | 66.19 | 65.02 | 64.88 | 64.75 | 64.61 | 63.19 | 63.13 | 61.77 |
| Number of Rainy Days (.01 inch or more) | 114 | 142 | 119 | 95 | 109 | 160 | 127 | 102 | 109 | 115 | 94 |
| Highest previous Rainfall .. .. | 67.14 | 76.12 | 60.41 | 85.83 | 66.16 | 95.03 | 68.51 | 72.86 | 64.45 | 85.26 | 80.75 |
| Lowest previous Rainfall .. .. .. | 66.82 | 53.42 | 43.61 | 61.53 | — | 48.22 | 60.68 | 50.43 | 56.90 | 57.55 | 47.45 |

## TABLE II—(*contd*).

SUMMARY OF RAINFALL IN INCHES FOR ALL STATIONS IN THE GOLD COAST FOR THE YEAR 1928.

| MONTH. | 23 Sunyani (14 years). | 24 Agona (3 years). | 25 Bekwai (15 years). | 26 Kibi (16 years). | 27 Kumasi (22 years). | 28 Dunkwa (14 years.) | 29 Tafo (3 years). | 30 Mampong (Ashanti) (3 years). | 31 Ho (7 years). | 32 Oda (14 years). | 33 Wa (12 years). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January .. .. .. .. .. | 0.00 | 0.00 | 2.33 | 1.30 | 0.32 | 1.15 | 0.98 | 0.00 | 4.25 | 0.11 | 0.00 |
| February .. .. .. .. .. | 0.14 | 1.17 | 0.00 | 2.02 | 1.09 | 0.57 | 3.60 | 1.65 | 0.29 | 0.79 | 0.53 |
| March .. .. .. .. .. | 4.17 | 4.69 | 8.58 | 3.61 | 9.76 | 6.84 | 4.86 | 5.93 | 2.60 | 2.48 | 3.64 |
| April .. .. .. .. .. | 16.58 | 4.34 | 4.65 | 9.92 | 5.12 | 4.94 | 5.69 | 7.29 | 3.36 | 7.39 | 3.13 |
| May .. .. .. .. .. .. | 9.08 | 9.22 | 6.54 | 5.82 | 7.02 | 6.11 | 7.66 | 8.48 | 7.08 | 6.25 | 8.18 |
| June .. .. .. .. .. .. | 4.54 | 6.61 | 6.95 | 6.50 | 6.03 | 11.15 | 5.05 | 7.45 | 9.68 | 9.49 | 4.91 |
| July .. .. .. .. .. .. | .03 | 3.03 | 3.38 | 8.17 | 5.41 | 4.71 | 6.72 | 1.39 | 5.81 | 2.73 | 6.83 |
| August .. .. .. .. .. | 2.00 | 2.02 | 3.52 | 3.15 | 2.50 | 1.49 | 3.67 | 2.49 | 4.63 | 4.70 | 9.88 |
| September .. .. .. .. | 7.28 | 12.46 | 8.94 | 7.48 | 9.88 | 6.55 | 7.59 | 7.08 | 7.82 | 5.15 | 13.32 |
| October .. .. .. .. .. | 9.26 | 13.52 | 10.20 | 6.68 | 8.12 | 9.53 | 8.79 | 14.38 | 10.55 | 10.00 | 6.59 |
| November .. .. .. .. .. | 1.83 | 2.25 | 3.78 | 3.64 | 2.40 | 4.42 | 2.76 | 1.92 | 0.87 | 4.64 | 0.20 |
| December .. .. .. .. .. | 0.00 | 1.03 | 0.92 | 0.99 | 1.53 | 1.36 | 1.33 | 0.00 | 1.02 | 4.04 | 0.00 |
| Total .. .. .. .. | 60.91 | 60.34 | 59.79 | 59.28 | 59.18 | 58.82 | 58.70 | 58.06 | 57.96 | 57.88 | 57.21 |
| Number of Rainy Days (.01 inch or more) | 77 | 123 | 116 | 151 | 128 | 116 | 84 | 19 | 106 | 139 | 98 |
| Highest previous Rainfall .. .. | 69.47 | 77.10 | 104.90 | 79.90 | 70.40 | 77.91 | 62.83 | 59.96 | 60.52 | 83.75 | 54.73 |
| Lowest previous Rainfall .. .. .. | 41.30 | 67.15 | 46.21 | 45.77 | 40.07 | 45.55 | 61.39 | 52.51 | 48.38 | 43.61 | 29.08 |

## Summary of Rainfall in inches for all Stations in the Gold Coast for the Year 1928.

| Month. | 34 Wenchi (7 years). | 35 Asromaso (2 years). | 36 Angu (3 years). | 37 Kpeve (2 years). | 38 Bole (2 years). | 39 Sekondi (25 years). | 40 Goaso (5 years). | 41 Koforidua (7 years). | 42 Asamankese (6 years). | 43 Lawra (3 years). | 44 Mansu (15 years). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January .. .. .. .. .. | 0.29 | 0.63 | 0.73 | 1.85 | 0.00 | 0.15 | 0.04 | 0.19 | 0.13 | 0.00 | 0.75 |
| February .. .. .. .. .. | 0.30 | 0.11 | 1.48 | 3.04 | 0.00 | 0.27 | 0.84 | 0.50 | 1.09 | 0.00 | 2.86 |
| March .. .. .. .. .. | 2.70 | 9.26 | 8.54 | 4.38 | 6.46 | 4.90 | 4.03 | 7.52 | 4.36 | 1.86 | 3.32 |
| April .. .. .. .. .. | 10.38 | 4.55 | 2.70 | 3.69 | 6.37 | 4.19 | 6.92 | 6.61 | 4.82 | 2.07 | 0.20 |
| May .. .. .. .. .. .. | 7.02 | 6.08 | 7.24 | 2.23 | 5.33 | 12.59 | 5.65 | 5.13 | 8.17 | 3.20 | 6.85 |
| June .. .. .. .. .. .. | 9.51 | 10.41 | 11.51 | 10.19 | 6.38 | 12.39 | 6.19 | 6.08 | 4.71 | 6.26 | 14.25 |
| July .. .. .. .. .. .. | 2.87 | 1.72 | 1.04 | 3.31 | 4.55 | 1.22 | 5.05 | 4.07 | 3.41 | 5.33 | 2.80 |
| August .. .. .. .. .. | 2.57 | 1.85 | 3.13 | 5.62 | 7.39 | 1.35 | 1.59 | 2.07 | 3.34 | 9.01 | 2.85 |
| September .. .. .. .. | 7.28 | 9.75 | 2.34 | 9.96 | 11.39 | 6.55 | 10.21 | 6.56 | 3.13 | 16.05 | 4.19 |
| October .. .. .. .. .. | 10.56 | 8.96 | 9.15 | 6.72 | 5.77 | 3.04 | 8.68 | 4.25 | 8.03 | 6.17 | 7.17 |
| November .. .. .. .. .. | 3.17 | 1.21 | 3.18 | 0.34 | 0.00 | 2.74 | 2.28 | 3.77 | 3.94 | 0.00 | 3.59 |
| December .. .. .. .. .. | 0.21 | 0.00 | 3.18 | 2.32 | 0.00 | 2.87 | 0.00 | 3.83 | 3.27 | 0.00 | 0.74 |
| Total .. .. .. .. | 56.86 | 54.53 | 54.22 | 53.65 | 53.64 | 52.26 | 51.48 | 50.58 | 50.40 | 49.95 | 49.57 |
| Number of Rainy Days (.01 inch or more) | 85 | 104 | 86 | 126 | 95 | 108 | 101 | 121 | 138 | 82 | 121 |
| Highest previous Rainfall .. .. | 60.95 | 68.36 | 52.95 | 49.80 | 54.62 | 57.76 | 59.50 | 55.13 | 77.47 | 53.50 | 83.70 |
| Lowest previous Rainfall .. .. .. | 53.40 | — | 49.58 | — | — | 32.98 | 44.94 | 51.78 | 51.43 | 36.43 | 46.90 |

## TABLE II—(*contd*).

SUMMARY OF RAINFALL IN INCHES FOR ALL STATIONS IN THE GOLD COAST FOR THE YEAR 1928.

| MONTH. | 45 Ajua (9 years). | 46 Asuansi (20 years). | 47 Yendi (7 years). | 48 Akropong (Akwapim) (2 years). | 49 Salaga (14 years). | 50 Aburi (38 years). | 51 Akuse (14 years). | 52 Navrongo (3 years). | 53 Zuarangu (11 years). | 54 Gambaga (4 years). | 55 Tamale (19 years). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.04 | 0.59 | 0.00 | 0.25 | 0.00 | 1.25 | 0.00 | 0.01 | 0.00 | 0.01 | 0.00 |
| February | 1.30 | 4.32 | 0.00 | 0.33 | 0.00 | 1.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| March | 3.17 | 2.88 | 1.53 | 2.66 | 1.48 | 2.54 | 2.22 | 0.03 | 0.38 | 0.59 | 0.79 |
| April | 1.35 | 3.57 | 3.48 | 6.12 | 10.74 | 4.80 | 8.86 | 2.89 | 2.51 | 3.50 | 4.78 |
| May | 12.29 | 7.18 | 4.27 | 8.48 | 5.81 | 6.71 | 7.67 | 2.78 | 1.56 | 3.65 | 3.80 |
| June | 17.20 | 9.93 | 5.40 | 4.62 | 4.64 | 4.86 | 3.52 | 4.55 | 5.03 | 4.50 | 4.54 |
| July | 0.90 | 2.56 | 7.01 | 5.03 | 2.86 | 4.24 | 3.50 | 6.64 | 7.80 | 7.11 | 3.17 |
| August | 1.25 | 2.37 | 9.09 | 0.81 | 4.50 | 2.38 | 0.14 | 12.19 | 10.71 | 10.23 | 10.84 |
| September | 2.55 | 3.12 | 10.44 | 4.28 | 9.77 | 3.57 | 8.13 | 10.26 | 9.44 | 8.06 | 4.89 |
| October | 3.58 | 7.01 | 6.42 | 10.87 | 4.70 | 7.11 | 5.92 | 3.94 | 3.73 | 3.28 | 6.96 |
| November | 3.62 | 1.59 | 0.00 | 2.76 | 1.70 | 3.99 | 2.75 | 0.00 | 0.00 | 0.01 | 0.00 |
| December | 2.29 | 3.14 | 0.00 | 1.17 | 0.00 | 2.12 | 1.68 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 49.54 | 48.26 | 47.64 | 47.38 | 46.20 | 45.24 | 44.39 | 43.29 | 41.16 | 40.94 | 39.77 |
| Number of Rainy Days (.01 inch or more) | 68 | 133 | 69 | 86 | 104 | 117 | 60 | 78 | 60 | 74 | 85 |
| Highest previous Rainfall | 49.03 | 74.17 | 67.12 | — | 64.52 | 73.16 | 58.98 | 40.22 | 51.62 | 56.47 | 61.77 |
| Lowest previous Rainfall | 36.81 | 35.62 | 43.92 | 29.01 | 37.79 | 32.09 | 35.14 | 28.66 | 37.93 | 34.75 | 32.36 |

## TABLE II—(*contd*).

### Summary of Rainfall in inches for all Stations in the Gold Coast for the Year 1928.

| Month. | 56 Nsawam (3 years). | 57 Saltpond (14 years). | 58 Bawku (2 years). | 59 Odumase (4 years). | 60 Abra (7 years). | 61 Cape Coast (1 year). | 62 Keta (23 years). | 63 Accra (42 years). | 64 Achimota (4 years). | 65 Labadi (6 years). | 66 Amedjofe (9 months). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.00 | 0.02 | 0.00 | 0.00 | 0.06 | 0.09 | 0.25 | 0.15 | 0.12 | 0.31 | — |
| February | 0.20 | 0.38 | 0.00 | 0.67 | 0.94 | 1.16 | 0.00 | 0.57 | 0.22 | 0.00 | — |
| March | 1.77 | 6.95 | 2.12 | 4.38 | 3.21 | 2.47 | 4.40 | 2.92 | 2.53 | 2.81 | — |
| April | 1.23 | 5.51 | 2.50 | 2.75 | 4.21 | 5.40 | 4.70 | 3.59 | 3.42 | 2.93 | 8.58 |
| May | 6.44 | 10.29 | 0.78 | 5.30 | 7.34 | 8.47 | 8.65 | 9.05 | 6.58 | 6.96 | 4.88 |
| June | 6.05 | 3.14 | 4.54 | 3.64 | 5.74 | 5.98 | 1.25 | 1.82 | 3.20 | 1.02 | 9.00 |
| July | 1.20 | 0.67 | 5.75 | 2.66 | 0.60 | 0.74 | 0.25 | 0.55 | 1.34 | 0.51 | 5.51 |
| August | 1.93 | 0.49 | 11.07 | 0.83 | 1.29 | 1.13 | 0.55 | 0.46 | 0.36 | 0.63 | 8.79 |
| September | 3.78 | 1.06 | 8.90 | 8.45 | 1.00 | 0.66 | 1.80 | 1.18 | 1.73 | 1.37 | 10.76 |
| October | 11.80 | 4.25 | 2.63 | 5.02 | 4.66 | 5.36 | 5.55 | 2.41 | 2.76 | 0.66 | 8.76 |
| November | 3.80 | 0.80 | 0.00 | 0.53 | 2.60 | 0.77 | 1.20 | 0.17 | 0.96 | 0.05 | 3.43 |
| December | 1.13 | 4.29 | 0.00 | 2.87 | 4.13 | 2.32 | 0.00 | 4.73 | 3.59 | 1.40 | 0.00 |
| Total | 39.33 | 38.85 | 38.29 | 37.10 | 35.78 | 34.55 | 28.60 | 27.60 | 26.81 | 18.65 | 59.71 |
| Number of Rainy Days (.01 inch or more) | 63 | 59 | 69 | 72 | 91 | 81 | 46 | 93 | 51 | 53 | 96 |
| Highest previous Rainfall | 55.40 | 43.80 | 39.37 | 49.77 | 34.18 | — | 51.44 | 44.20 | 28.54 | 36.87 | — |
| Lowest previous Rainfall | 49.01 | 19.73 | — | 42.40 | 25.20 | — | 13.88 | 10.84 | 21.09 | 10.78 | — |

TABLE II—(*continued*).

SUMMARY OF RAINFALL IN INCHES FOR ALL STATIONS IN THE GOLD COAST FOR THE YEAR 1928.

| Month. | 67 Akropong (Ashanti) (11 months). | 68 Bonso (10 months). | 69 Kajebi (8 months). | 70 Dafo (9 months). | 71 Otrokpe (10 months). | 72 Akpafu (9 months). | 73 Honuta (E.F.P.S.) (7 months). | 74 Mpayo (P.S.) (6 months). | 75 Anyinam (4 months). | 76 Botoe (E.F.S.). (7 months) | 77 Djoje (E F P.S.) (7 months). | 78 Winneba (6 months). | 79 Kpandu (2 months). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January .. .. .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — |
| February .. .. .. .. | 0.08 | — | — | — | — | — | — | — | — | — | — | — | — |
| March .. .. .. .. .. | 7.36 | 4.51 | — | — | 5.68 | — | — | — | — | — | — | — | — |
| April .. .. .. .. .. | 4.90 | 5.53 | — | 5.50 | 7.74 | 5.10 | — | — | — | — | — | — | — |
| May .. .. .. .. .. | 6.34 | 6.17 | 4.85 | 3.55 | 6.45 | 3.31 | — | — | — | — | — | — | — |
| June .. .. .. .. .. | 7.29 | 5.31 | 6.29 | 9.29 | 4.49 | 9.32 | 9.13 | — | — | 2.64 | 1.11 | — | — |
| July .. .. .. .. .. | 3.12 | 8.04 | 7.41 | 5.74 | 2.61 | 7.57 | 10.00 | 6.76 | — | 3.87 | 1.21 | 0.00 | — |
| August .. .. .. .. .. | 2.51 | 3.17 | 5.61 | 7.61 | 0.94 | 4.74 | 7.52 | 10.32 | — | 2.54 | 1.60 | 0.63 | — |
| September .. .. .. .. | 13.61 | 6.18 | 11.63 | 8.09 | 6.04 | 5.16 | 9.95 | 10.29 | 10.16 | 2.15 | 3.42 | 1.45 | — |
| October .. .. .. .. | 10.38 | 5.18 | 9.21 | 7.47 | 7.96 | 7.05 | 6.98 | 7.58 | 8.26 | 4.24 | 4.58 | 2.42 | — |
| November .. .. .. .. | 2.13 | 4.88 | 2.74 | 0.84 | 1.72 | 0.84 | 0.00 | 1.15 | 6.18 | 0.00 | 0.00 | 0.17 | 3.52 |
| December .. .. .. .. | 0.51 | 2.49 | 3.38 | 2.03 | 2.23 | 2.20 | 2.56 | 1.02 | 1.10 | 2.71 | 2.56 | 2.65 | 0.80 |
| Total .. .. .. | 58.23 | 51.56 | 51.12 | 50.12 | 45.86 | 45.29 | 44.94 | 37.12 | 25.70 | 18.13 | 14.48 | 7.32 | 4.32 |
| Number of Rainy days (.01 inch or more) .. .. .. .. | 112 | 117 | 79 | 103 | 64 | 105 | 79 | 67 | 74 | 48 | 29 | 32 | 9 |
| Highest previous Rainfall .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Lowest previous Rainfall .. .. | — | — | — | — | — | — | — | — | — | — | — | — | — |

# TABLE III.

## Temperature Records for the Year ending 31st December, 1928.

| | Keta. | | | Kpeve. | | | Tamale. | | | Sekondi. | | | Accra. | | | Axim. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. |
| January .. | 85.3 | 74.8 | 80.0 | 90.2 | 68.1 | 79.1 | 97.6 | 59.1 | 78.3 | 88.2 | 73.2 | 80.7 | 87.1 | 74.9 | 81.0 | 85.2 | 73.2 | 79.2 |
| February .. | 85.1 | 75.4 | 80.2 | 96.7 | 70.1 | 83.4 | 98.9 | 59.4 | 79.2 | 91.2 | 71.4 | 81.3 | 88.1 | 72.5 | 80.3 | 86.6 | 70.8 | 78.7 |
| March .. .. | 85.3 | 72.1 | 78.7 | 95.3 | 72.6 | 83.9 | 102.3 | 67.2 | 84.7 | 88.6 | 75.2 | 81.9 | 86.7 | 76.0 | 81.3 | 85.8 | 74.7 | 80.2 |
| April .. .. | 85.3 | 72.1 | 78.7 | 94.9 | 73.2 | 84.0 | 98.4 | 66.7 | 82.5 | 88.2 | 75.2 | 81.7 | 87.2 | 75.5 | 81.4 | 85.5 | 74.8 | 80.2 |
| May .. .. | 85.8 | 72.7 | 79.2 | 93.4 | 72.3 | 82.9 | 93.2 | 65.5 | 84.5 | 87.3 | 74.6 | 80.9 | 85.5 | 75.2 | 80.3 | 84.9 | 75.7 | 80.3 |
| June .. .. | 85.5 | 76.9 | 81.2 | 90.2 | 70.8 | 80.5 | 89.8 | 66.4 | 78.1 | 83.3 | 73.5 | 78.4 | 84.0 | 73.7 | 78.9 | 81.4 | 75.6 | 78.5 |
| July .. .. | 87.8 | 80.5 | 84.1 | 86.2 | 72.4 | 79.3 | 89.3 | 71.9 | 80.6 | 81.7 | 72.2 | 76.9 | 80.9 | 73.1 | 77.0 | 82.6 | 70.3 | 76.4 |
| August .. | 88.3 | 80.4 | 84.2 | 87.1 | 66.7 | 76.9 | 85.5 | 71.7 | 78.6 | 80.5 | 71.2 | 75.9 | 78.9 | 71.9 | 75.4 | 82.5 | 71.3 | 76.9 |
| September .. | 88.4 | 80.5 | 84.4 | 87.2 | 71.2 | 79.2 | 86.8 | 71.0 | 78.9 | 81.3 | 71.3 | 76.3 | 80.9 | 72.7 | 81.8 | 81.4 | 74.5 | 77.9 |
| October .. | 90.5 | 88.6 | 89.6 | 89.2 | 70.7 | 79.9 | 89.5 | 71.1 | 80.3 | 84.7 | 72.7 | 78.7 | 84.5 | 73.9 | 79.2 | 81.4 | 76.1 | 78.8 |
| November .. | 90.4 | 81.0 | 85.7 | 91.6 | 71.2 | 81.4 | 94.3 | 70.2 | 82.2 | 88.2 | 74.7 | 81.5 | 87.3 | 75.1 | 82.2 | 82.1 | 77.1 | 79.6 |
| December .. | 91.9 | 86.2 | 89.0 | 89.7 | 69.0 | 79.3 | 94.1 | 65.1 | 79.6 | 88.6 | 73.0 | 80.8 | 87.5 | 73.9 | 80.7 | 81.1 | 76.0 | 78.5 |
| Mean .. | 87.6 | 78.5 | 82.9 | 91.0 | 70.7 | 80.8 | 93.3 | 67.1 | 80.2 | 86.0 | 73.2 | 79.6 | 84.9 | 74.0 | 79.4 | 83.8 | 74.2 | 79.0 |

## TABLE III—(*contd*).

### Temperature Records for the year ending 31st December, 1928.

| Month. | Kumasi. | | | Achimota. | | | Aburi. | | | Kintampo. | | | Begoro. | | | Asuansi. | | | Akuse. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. | Max. | Min. | Mean. |
| January | 91.5 | 66.1 | 78.8 | 86.8 | 72.2 | 79.5 | 87.1 | 70.8 | 78.9 | 92.0 | 58.3 | 75.1 | 87.1 | 72.3 | 79.7 | 86.2 | 69.2 | 77.7 | 95.6 | 56.7 | 76.2 |
| February | 94.9 | 62.4 | 78.7 | 90.4 | 70.5 | 80.4 | 90.8 | 71.2 | 81.0 | 96.8 | 60.5 | 78.6 | 91.3 | 67.2 | 79.2 | 90.1 | 64.4 | 77.2 | 99.4 | 54.5 | 76.9 |
| March .. | 91.5 | 70.7 | 81.1 | 85.9 | 75.0 | 80.4 | 89.3 | 71.3 | 80.3 | 98.6 | 64.9 | 81.7 | 89.5 | 68.8 | 79.2 | 88.4 | 72.7 | 80.6 | 99.1 | 59.4 | 79.3 |
| April .. | 90.8 | 71.2 | 81.0 | 84.2 | 72.8 | 78.5 | 89.1 | 71.1 | 80.1 | 97.1 | 66.9 | 82.0 | 88.6 | 69.0 | 78.8 | 87.6 | — | — | 95.5 | 58.6 | 77.0 |
| May .. | 89.8 | 70.8 | 80.3 | 84.2 | 71.8 | 78.0 | 87.3 | 69.8 | 78.5 | 92.7 | 62.5 | 77.6 | 85.9 | 68.2 | 77.0 | 86.4 | — | — | 92.6 | 58.1 | 75.4 |
| June .. | 87.4 | 71.0 | 79.2 | 84.0 | 71.0 | 77.5 | 84.4 | 69.7 | 77.0 | 88.9 | 69.8 | 79.3 | 82.6 | 68.2 | 75.4 | 83.3 | 70.7 | 77.0 | 91.5 | 55.2 | 73.3 |
| July .. | 84.4 | 69.8 | 77.1 | 82.2 | 71.3 | 76.6 | 79.5 | 66.8 | 73.1 | 86.2 | 65.5 | 75.8 | 82.0 | 67.2 | 74.6 | 80.7 | 69.8 | 75.2 | 88.0 | 52.0 | 70.0 |
| August .. | 83.1 | 68.8 | 75.9 | 82.3 | 71.5 | 76.9 | 79.4 | 65.9 | 72.6 | 85.1 | 62.6 | 73.8 | 79.1 | 66.8 | 72.9 | 78.4 | 69.0 | 73.7 | 88.8 | 55.7 | 72.3 |
| September | 86.1 | 69.7 | 77.9 | 81.9 | 72.1 | 77.0 | 81.2 | 67.4 | 74.3 | 87.6 | 62.9 | 75.3 | 82.2 | 66.9 | 74.6 | 78.9 | 70.5 | 74.7 | 90.6 | 52.7 | 71.6 |
| October | 89.3 | 70.4 | 79.9 | 85.3 | 71.5 | 78.4 | 83.6 | 69.1 | 76.3 | 90.1 | 62.2 | 76.1 | 85.7 | 67.1 | 76.4 | 84.3 | 70.3 | 77.3 | 91.6 | 53.1 | 72.4 |
| November | 90.0 | 69.5 | 79.8 | 87.5 | 74.3 | 80.8 | 85.5 | 71.2 | 78.5 | 93.0 | 62.3 | 77.7 | 88.9 | 67.4 | 78.1 | 86.8 | 69.5 | 78.1 | 94.5 | 53.9 | 74.2 |
| December | 89.4 | 64.7 | 77.0 | 87.4 | 76.4 | 81.9 | 85.9 | 70.6 | 78.2 | 92.5 | 60.5 | 78.0 | 86.8 | 66.3 | 76.6 | 87.4 | 68.2 | 77.8 | 95.8 | 56.7 | 76.2 |
| Mean .. | 89.0 | 68.8 | 78.9 | 85.2 | 72.4 | 78.8 | 85.3 | 69.6 | 77.4 | 91.7 | 63.2 | 77.4 | 85.8 | 68.8 | 77.3 | 84.9 | 69.5 | 77.2 | 93.7 | 55.6 | 74.6 |

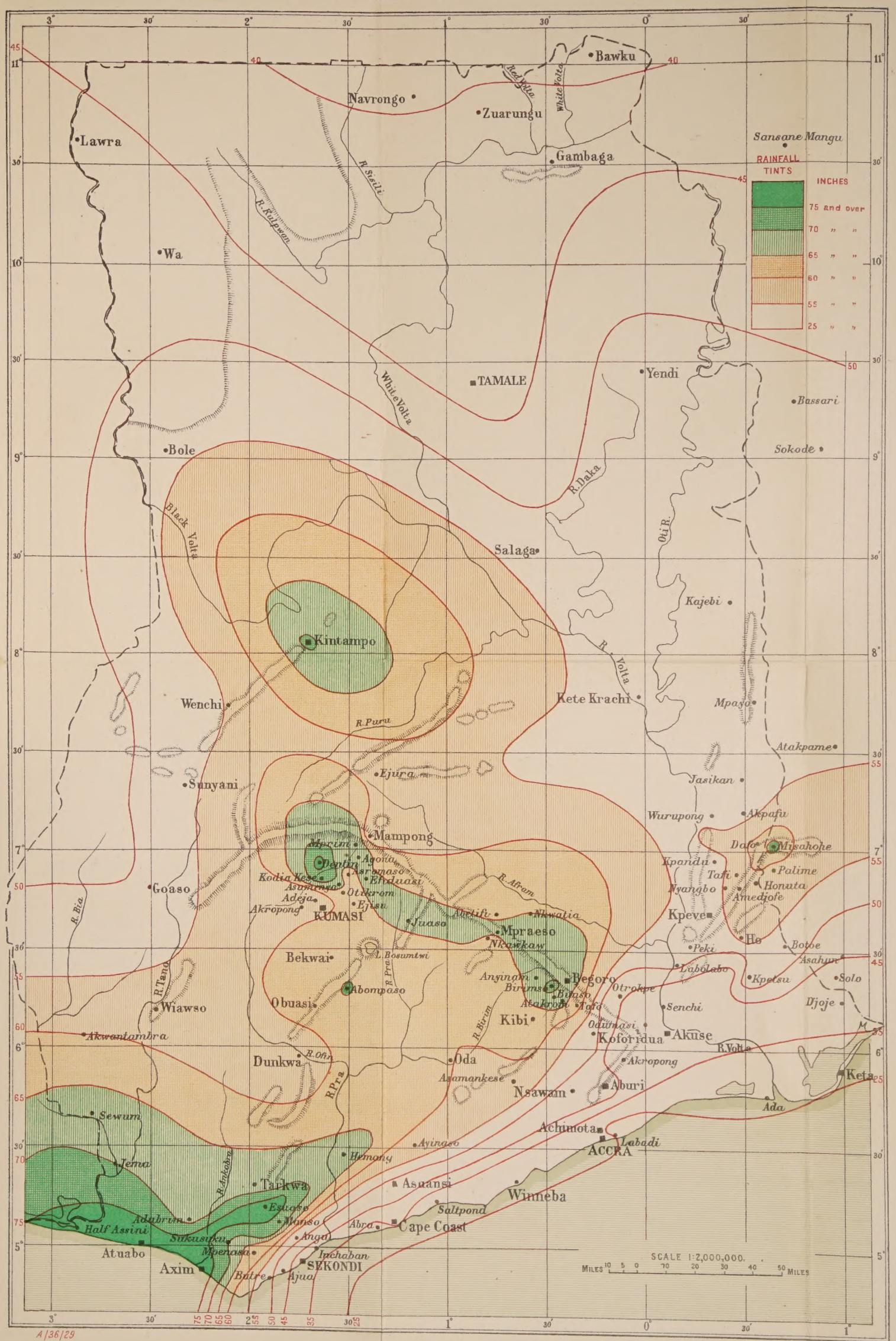
## TABLE IV.

### Relative Humidity, 1928.

| Month. | Axim. | Begoro. | Aburi. | Asuansi. | Achimota. | Sekondi. | Kumasi. | Kpeve. | Akuse. | Accra. | Kintampo. | Keta. | Tamale. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January .. .. | 88.8 | 83.8 | 85.8 | 80.4 | 71.7 | 83.2 | 78.3 | 80.8 | 68.5 | 76.0 | 50.8 | — | 35.6 |
| February .. .. | 75.7 | 85.3 | 60.8 | 81.9 | 56.2 | 67.4 | 63.0 | 59.9 | 50.5 | 58.6 | 43.8 | 72.5 | 39.9 |
| March .. .. | 88.8 | 81.6 | 83.0 | 80.5 | 80.2 | 78.5 | 81.2 | 75.4 | 73.7 | 75.0 | 66.7 | 76.8 | 53.6 |
| April .. .. | 81.2 | 85.2 | 83.0 | 78.4 | 82.0 | 78.1 | 80.9 | 77.8 | 83.7 | 74.3 | 66.6 | 61.5 | 65.0 |
| May .. .. .. | 84.7 | 87.1 | 88.0 | 79.1 | 82.5 | 79.5 | 81.8 | 81.5 | 87.7 | 76.7 | 65.7 | 68.7 | 68.4 |
| June .. .. .. | 85.4 | 86.9 | 90.0 | 84.2 | 88.2 | 84.0 | 83.5 | 83.8 | 91.7 | 72.6 | 76.8 | 69.9 | 74.8 |
| July .. .. .. | 95.0 | 89.5 | 87.0 | 85.8 | 91.0 | 85.5 | 81.1 | 87.6 | 83.0 | 79.6 | 82.1 | 63.6 | 77.7 |
| August .. .. | 90.2 | 88.8 | 80.0 | 92.0 | 87.0 | 84.2 | 86.3 | 80.0 | 69.3 | 81.8 | 90.8 | 70.6 | 81.7 |
| September .. .. | 91.0 | 80.4 | 95.7 | 91.6 | 88.6 | 87.2 | 88.8 | 81.7 | 73.8 | 80.7 | 89.3 | 67.4 | 81.4 |
| October .. .. | 90.4 | 84.7 | 87.6 | 88.6 | 93.0 | 83.2 | 83.8 | 79.4 | 74.2 | 71.7 | 82.0 | 75.0 | 75.6 |
| November .. .. | 88.9 | 86.1 | 88.4 | 86.1 | 90.0 | 81.0 | 80.9 | 73.0 | 78.1 | 69.9 | 75.7 | 75.0 | 58.9 |
| December .. .. | 87.8 | 83.1 | 83.5 | 83.2 | 83.1 | 83.0 | 83.7 | 80.9 | 75.9 | 72.3 | 76.8 | 53.0 | 48.4 |
| Mean .. .. .. | 87.3 | 85.9 | 85.3 | 85.1 | 83.5 | 81.2 | 81.1 | 78.5 | 75.8 | 72.4 | 72.3 | 68.5 | 63.4 |

# DEPARTMENT OF AGRICULTURE.

## Mean Distribution of Rainfall
## (to the end of 1928)




A/36/29

Survey H.Q. Accra, 1929.

## List of Rainfall Recording Stations.

| | Name. | Amount Inches. | No. of years of record. |
|---|---|---|---|
| 1. | Abetifi | (42.99) | 10 months |
| 2. | Abomposo | 68.06 | 16 years |
| 3. | Abra | 33.02 | 7 „ |
| 4. | Aburi | 47.73 | 38 „ |
| 5. | Accra | 27.43 | 42 „ |
| 6. | Achimota | 25.11 | 4 „ |
| 7. | Ada | 32.05 | 7 „ |
| 8. | Adeja | 70.65 | 1 year |
| 9. | Adubrim | 68.46 | 3 years |
| 10. | Agona | 68.20 | 3 „ |
| 11. | Ajua | 45.40 | 9 „ |
| 12. | Akpafu | (45.29) | 9 months |
| 13. | Akropong | 38.20 | 2 years |
| 14. | Akropong (Ash.) | (58.23) | 11 months |
| 15. | Akuse | 41.32 | 14 years |
| 16. | Akwantambra | 60.00 | — |
| 17. | Amedjofe | (59.71) | 9 months |
| 18. | Angu | 52.25 | 3 years |
| 19. | Anyinam | 65.80 | 21 „ |
| 20. | Asamankese | 49.44 | 6 „ |
| 21. | Asromasu | 54.94 | 2 „ |
| 22. | Asuansi | 49.97 | 20 „ |
| 23. | Asumenya | (34.88) | 6 months |
| 24. | Atokrom | 69.69 | 5 years |
| 25. | Atwabo | 92.37 | 2 „ |
| 26. | Axim | 76.64 | 14 „ |
| 27. | Ayinasu | 55.17 | 7 „ |
| 28. | Bawku | 38.83 | 2 „ |
| 29. | Begor | 67.71 | 7 „ |
| 30. | Bekwai | 63.26 | 15 „ |
| 31. | Birrims | 70.45 | 13 „ |
| 32. | Bole | 54.13 | 2 „ |
| 33. | Botoe | (18.15) | 7 months |
| 34. | Bunso | 68.86 | 8 years |
| 35. | Butre (Seysie) | 53.54 | 8 „ |
| 36. | Cape Coast | 39.31 | 7 „ |
| 37. | Dato | (50.12) | 9 months |
| 38. | Dentin | 86.63 | 2 years |
| 39. | Djoje | (14.48) | 7 months |
| 40. | Dunkwa | 56.32 | 14 years |
| 41. | Effiduase | 65.59 | 2 years |
| 42. | Ejisu | 61.78 | 3 „ |
| 43. | Ejura | 57.58 | 13 „ |
| 44. | Esuaso | 82.13 | 3 „ |
| 45. | Gambaga | 43.76 | 4 „ |
| 46. | Goaso | 51.02 | 5 „ |
| 47. | Half Assini | 77.09 | 7 „ |
| 48. | Hemang | 67.08 | 10 „ |
| 49. | Ho | 56.50 | 7 „ |
| 50. | Honuta | (44.94) | 7 months |
| 51. | Imprim | 67.22 | 7 years |
| 52. | Inchaban | 41.38 | 1 year |
| 53. | Jemma | 70.00 | — |
| 54. | Juaso | 65.50 | 13 years |
| 55. | Kajebi | (51.12) | 8 months |
| 56. | Keta | 26.75 | 23 years |
| 57. | Keta Kratchi | 50.78 | 10 „ |
| 58. | Kibi | 63.98 | 16 „ |
| 59. | Kintampo | 71.20 | 14 „ |
| 60. | Kodia Kese | 71.19 | 3 „ |
| 61. | Koforidua | 51.20 | 7 „ |
| 62. | Kpandu | 51.50 | 9 „ |
| 63. | Kpetsu | 52.38 | 4 „ |
| 64. | Kpeve | 51.72 | 2 „ |
| 65. | Kumasi | 58.53 | 22 „ |
| 66. | Labadi | 24.23 | 6 „ |
| 67. | Labolabo | 50.81 | 8 „ |
| 68. | Lawra | 46.63 | 3 „ |
| 69. | Mampong (Ash.) | 56.31 | 3 „ |
| 70. | Mansu | 70.56 | 15 „ |
| 71. | Mpayo | (37.12) | 6 months |
| 72. | Mpennasa | 62.49 | 4 years |
| 73. | Mpraeso | 67.34 | 11 „ |
| 74. | Navrongo | 37.39 | 3 „ |
| 75. | Nkawkaw | 64.65 | 3 „ |
| 76. | Nkwatia | 65.00 | 10 „ |
| 77. | Nsawam | 47.91 | 3 „ |
| 78. | Obuasi | 62.03 | 4 „ |
| 79. | Oda | 60.02 | 14 „ |
| 80. | Odumasi | 36.87 | 4 „ |
| 81. | Otikrom | 64.19 | 3 „ |
| 82. | Otrokpe | (45.86) | 10 months |
| 83. | Peki Blengo | 52.09 | 13 years |
| 84. | Salaga | 51.26 | 14 „ |
| 85. | Saltpond | 31.77 | 14 „ |
| 86. | Sekondi | 40.66 | 25 „ |
| 87. | Senchi | 40.00 | — |
| 88. | Siwum | 67.39 | 7 „ |
| 89. | Sukusuku | 70.00 | — |
| 90. | Sunyani | 54.13 | 14 years |
| 91. | Tafo | 61.31 | 3 „ |
| 92. | Tamale | 42.09 | 19 „ |
| 93. | Tarkwa | 68.28 | 25 „ |
| 94. | Wa | 46.59 | 12 „ |
| 95. | Wenchi | 55.02 | 7 „ |
| 96. | Wiawso | 56.99 | 12 „ |
| 97. | Winneba | 27.91 | 7 „ |
| 98. | Yendi | 53.08 | 7 „ |
| 99. | Zuarungu | 43.13 | 11 „ |

### GERMAN FIGURES.

| | | | |
|---|---|---|---|
| 1. | Asahun | 45.16 | 6 years |
| 2. | Atakpame | 53.46 | 9 „ |
| 3. | Bassari | 51.20 | — |
| 4. | Jasikan | 53.57 | 6 „ |
| 5. | Palime | 58.37 | 6 „ |
| 6. | Misahohe | 65.38 | 9 „ |
| 7. | Nyangbo | 56.26 | 8 „ |
| 8. | Sansane Mangu | 42.20 | — |
| 9. | Sokode | 52.03 | 9 „ |
| 10. | Solo | 43.80 | 9 „ |
| 11. | Tafi | 55.49 | 9 „ |
| 12. | Wurupong | 54.02 | 1 year |